47TH CONGRESS, 1st Session. } HOUSE OF REPRESENTATIVES. { Ex. Doc. 1, Part 2.

# REPORT

OF THE

# SECRETARY OF WAR;

BEING PART OF

## THE MESSAGE AND DOCUMENTS

COMMUNICATED TO THE

## TWO HOUSES OF CONGRESS

AT THE

BEGINNING OF THE FIRST SESSION OF THE FORTY-SEVENTH CONGRESS.

IN FOUR VOLUMES.



VOLUME III.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1882.

# REPORT

OF THE

# CHIEF OF ORDNANCE.

# REPORT

OF

# THE CHIEF OF ORDNANCE.

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WAR DEPARTMENT, ORDNANCE OFFICE,
*Washington, October* 1, 1881.

SIR: I have the honor to submit the following report of the principal operations of the Ordnance Department during the fiscal year ended June 30, 1881, with such remarks and recommendations as the interests of this branch of the military service seem to require.

The fiscal resources and expenditures of the department during the year were as follows, viz:

| | |
|---|---|
| Amount in the Treasury to the credit of appropriations on June 30, 1880. | $154,544 10 |
| Amount in the Treasury not reported to the credit of appropriations on June 30, 1880 | 7,155 44 |
| Amount in government depositories to the credit of disbursing officers and others on June 30, 1880 | 135,996 13 |
| Amount of appropriations for the service of the fiscal year ended June 30, 1881 | 1,840,696 24 |
| Amount refunded to ordnance appropriations in settling accounts during the fiscal year ended June 30, 1881 | 6,769 02 |
| Gross amount received during the fiscal year ended June 30, 1881, from sales to officers; from rents; from collections from troops on account of losses of, or damages to, ordnance stores; from Chicago, Rock Island and Pacific Railroad Company; from exchange of powder; from sales of condemned stores; and from all other sources not before mentioned. | 138,286 83 |
| Total | 2,283,447 76 |
| Amount of expenditures during the fiscal year ended June 30, 1881, including expenses attending sales of condemned stores, exchange of powder, &c | $1,637 593 79 |
| Amount deposited in Treasury during the fiscal year ended June 30, 1881, as proceeds of sales of government property | 64,308 55 |
| Amount lapsed into the Treasury from the appropriation "Ordnance material," under act of March 3, 1875, during the fiscal year ended June 30, 1881 | 2 80 |
| Amount turned into the "surplus fund" on June 30, 1881 | 3,042 75 |
| Amount in government depositories to the credit of disbursing officers and others on June 30, 1881 | 175,278 54 |
| Amounts transferred from ordnance appropriations in settling accounts during the fiscal year ended June 30, 1881 | 376 37 |
| Amount in the Treasury not reported to the credit of appropriations on June 30, 1881 | 2,658 85 |
| Amount in the Treasury to the credit of appropriations on June 30, 1881. | 400,186 11 |
| Total | 2,283,447 76 |

## STATIONS AND DUTIES.

The stations and duties of the officers remain about the same as reported last year, viz: two at the Ordnance Office, twenty-nine at the arsenals, armory, and powder depots; nine at the ordnance agency, on the Ordnance Board, and at the foundries; seven at the different military headquarters and ordnance depots; four at the Military Academy; two under the orders of the Honorable Secretary of the Interior; and two on leave of absence (sick). Captains Dutton and Pitman have, on application of the Secretary of the Interior, been detailed for duty in that department, and Lieutenant Lyle still continues on duty in the Life-Saving Service, under the Secretary of the Treasury. Under the operations of existing laws, two officers have been transferred to the department from the line of the Army, after passing satisfactory examinations preliminary thereto.

The recent death of Col. J. G. Benton, commanding the National Armory, has cast a gloom over the entire department. He was an officer of marked distinction, of the greatest professional attainments, with a public record without blemish, and a private life pure and noble. His death is a national loss. He gave to his country forty years of laborious and most valuable service, and has left a name and a memory that will be cherished by all lovers of the good and the true.

In the Revised Statutes are found the laws that fix the duties and responsibilities of the Ordnance Department. It provides armament for our extended sea-coast defenses, and arms and ordnance stores for the Army in all its branches, for the militia of the States and Territories, the Marine Corps of the Navy, all other governmental departments, when necessary to protect public money and property, and the thirty colleges authorized to receive arms for instruction. This is the mere supplying of the finished product. Its gravest responsibilities lie in the determination of the best war material, after long and close study and experiment, and its production of the best quality and workmanship. That the department has been fairly successful in its labors and operations, I cheerfully leave to the Army to decide.

*Rock Island Arsenal.*—The report of the commanding officer is herewith submitted. The erection of the workshops has been prosecuted with all expedition and economy.

*Benicia Arsenal.*—The appropriation made last session not being sufficient for the construction of the necessary workshops, work upon them has been postponed until Congress takes action on the estimate submitted. The necessity for the additional appropriation is most urgent, in view of the fact that Benicia is the only manufacturing arsenal on the Pacific coast, and should possess all the facilities and appliances to make it independent of our government workshops east of the Mississippi River.

*Piccatinny Powder Depot.*—The interesting report of the officer in

command is herewith submitted, with the hope that Congress will make liberal appropriations for this important establishment. Railroad facilities are absolutely essential to the economical and successful carrying out of the plans adopted, and to connect with the railroad system for prompt and rapid transportation of gunpowder.

*San Antonio Arsenal.*—Estimates have been submitted for the necessary buildings at this arsenal. It supplies the entire Texas frontier, and its capacity for storage and repairs should be greatly enlarged. Most of the buildings are old and worthless, and should be at once replaced.

*Frankford Arsenal.*—The report of its operations is submitted. As it is the government cartridge factory, the arsenal should be kept in the best condition. The wall on the creek and river needs renovating, and an appropriation should be made.

*Testing Machine at Watertown Arsenal.*—The report of the commanding officer will be submitted for transmission to Congress.

## SMALL-ARMS.

During the fiscal year ending June 30, 1881, there were manufactured at the National Armory 26,528 rifles and carbines. Much miscellaneous work in repairs of arms, spare parts, &c., was done.

On the 1st of July there were in store as a reserve supply, including those manufactured during the year, only 37,526 arms. This is but little more than the annual consumption, and increased appropriations for accumulating a larger reserve are indispensable to the safety of the country.

On my recommendation Congress at its last session provided for convening a board of officers to examine magazine guns, with a view to the selection of some of the best for trial in service. The board is now in session.

In this connection the question of ammunition becomes an important one. The capabilities of any arm can only be utilized by those experienced in its use, and target practice in its fullest development has become a necessity in all armies. The expenditure of ammunition for this purpose in considerable quantities, or in quantities sufficient to make our soldiers expert marksmen, is not waste or a useless expenditure. On the contrary, it is of vital importance. In an Indian fight the best marksman is the strongest man. Victory is not for the man of muscle, but the result of the quick eye and cool nerve of the fine shot. If our soldiers can pick off an Indian at one thousand yards, or even at five hundred yards, with unerring certainty, the Indian's occupation is gone. But we can make marksmen of our soldiers only by continued practice, and by a constant expenditure of ammunition. This costs money, but our Army is very small, and lack of numbers must be compensated by the greatest efficiency possible.

A close calculation shows that to supply each soldier with the ammu-

nition required for target and gallery practice will cost $8.50 annually per man, or a total of $212,500.

Besides this, we require money for the ammunition for actual service and for a reserve supply. In my opinion the least amount that should be appropriated for ammunition is $300,000.

## MILITIA.

In my last annual report I had the honor to refer at length to a very exhaustive report from the House Committee on the Militia on the powers of Congress and the rights of the States, accompanied by a bill.

Under the Constitution, Congress has the power:

To provide for calling forth the militia to execute the laws of the Union, suppress insurrections, and repel invasions.

To provide for organizing, arming, and disciplining the militia, and for governing such part of them as may be employed in the service of the United States, reserving to the States, respectively, the appointment of the officers and the authority of training the militia according to the discipline prescribed by Congress.

To make all laws which shall be necessary and proper for carrying into execution the foregoing powers, and all other powers vested by this Constitution in the Government of the United States, or in any department or officer thereof.

No State shall, without the consent of Congress, * * * keep troops, or ships of war, in time of peace, * * * or engage in war, unless actually invaded, or in such imminent danger as will not admit of delay.

For the purpose of more completely arming and equipping the whole body of militia, the permanent appropriation of $200,000 made in 1808 should be largely increased, and I so earnestly recommend. In war the country must depend upon its citizens for soldiers. Its militia, well armed, well organized, and thoroughly disciplined, must constitute its armed force. The absence of a large standing army must be compensated by the number of its citizen soldiers, and a large increase to the appropriation, as herein suggested, is the most economical way of solving this important question of a large armed force with a small standing army.

## RETIRED LIST.

There are now ten ordnance storekeepers allowed by law. Of these, three are on permanent sick leave, being totally incapacitated for duty. Several others are over sixty-two years of age. Both the old and the sick should be retired. The law of June 23, 1874, provides for the extinction of the grade of storekeeper by casualties. The retirement of these old and sick officers has been recommended, but the crowded condition of the retired list and the stronger claims of others have prevented any action. The interest of the public service, substantial economy, and the spirit of the laws call for favorable consideration.

In this connection I venture the expression of the opinion that the well-being and efficiency of the Army require the peremptory retirement of officers at the age of sixty-two years. The Army law governing retirements should be made to conform to that of the Navy, fixing by

statute the age when the officer is retired. Such a law would shield the officer from apparent invidious selections to his disadvantage, and give, what is so much needed, a healthy flow of promotion to the advantage of the young and vigorous.

## ARMAMENT OF FORTIFICATIONS.

The "Act making appropriations for fortifications and other works of defense, and for the armament thereof, for the fiscal year ending June 30, 1882, and for other purposes," approved March 3, 1881, provides:

And the President is authorized to select a board, to consist of one engineer officer, two ordnance officers, and two officers of artillery, whose duty it shall be to make examinations of all inventions of heavy ordnance and improvements of heavy ordnance and projectiles that may be presented to them, including guns now being constructed or converted under direction of the Ordnance Bureau; and said board shall make detailed report to the Secretary of War, for transmission to Congress, of such examination, with recommendation as to what inventions are worthy of actual test, and the estimated cost of such test; and the sum of twenty-five thousand dollars, or so much thereof as may be necessary, is hereby appropriated for such purpose.

In conformity with the foregoing act, a board of officers has been appointed and is now in session for the purpose of making examinations of all inventions referred to in the law, and making a detailed report of such examinations, with recommendation as to what inventions are worthy of actual test, and the estimated cost of such test.

As its report will undoubtedly be made and transmitted to Congress early the next session, I will at this time merely submit reports from the Constructor of Ordnance and the Ordnance Board on the progress made and the results obtained during the past year.

## PAPERS ON ORDNANCE SUBJECTS, ETC.

I have also to transmit several very valuable and interesting papers on ordnance and other subjects, by officers of the department.

## CLERICAL FORCE.

The clerical force, including the twenty enlisted men allowed by law, is found ample to perform the labors of this bureau. But I have again the honor to recommend that *three* clerks of class four may be provided, to take charge of the three important divisions of this office. I have also to recommend that the pay of the chief clerk may be increased. If the compensation should be commensurate to the capacity, experience, and to the duty performed, his present salary is entirely inadequate. I know of no more valuable and indispensable public servants than the chief clerks of our bureaus, and equal talents and services would in private business exact much larger compensation than is allowed by Congress. This matter is respectfully submitted to your favorable consideration.

I have the honor to submit the following papers, heretofore referred to

*Appendix* 1.—Statement of principal articles procured by fabrication at the arsenals during the year ended June 30, 1881.

*Appendix* 2.—Statement of principal articles procured by purchase at the arsenals during the year ended June 30, 1881.

*Appendix* 3.—Statement of ordnance, ordnance stores, &c., issued to the military establishment, exclusive of the militia, during the year ended June 30, 1881.

*Appendix* 4.—Apportionment for the fiscal year ended June 30, 1881, of the annual appropriation of $200,000 for arming and equipping the militia, under sections 1661 and 1667, Revised Statutes.

*Appendix* 5.—Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1880, to June 30, 1881, under section 1667, Revised Statutes.

*Appendix* 6.—Statement of ordnance, ordnance stores, &c., distributed to colleges from July 1, 1880, to June 30, 1881, under section 1225, Revised Statutes.

*Appendix* 7.—Statement of arms and ammunition issued to the executive departments during the year ended June 30, 1881, under the provisions of the act of March 3, 1879.

*Appendix* 8.—Report of action taken during the year ended June 30, 1881, under the provisions of the act approved March 3, 1881.

*Appendix* 9.—Report of the principal operations at the Rock Island Arsenal, Illinois, during the fiscal year ended June 30, 1881, Major D. W. Flagler, Ordnance Department, commanding.

*Appendix* 10.—Report of the principal operations at the Benicia Arsenal, California, during the fiscal year ended June 30, 1881, Col. J. McAllister, Ordnance Department, commanding.

*Appendix* 11.—Report of the principal operations at the Piccatinny Powder Depot, New Jersey, during the fiscal year ended June 30, 1881, Major F. H. Parker, Ordnance Department, commanding.

*Appendix* 12.—Report of the principal operations at the Frankford Arsenal, Pennsylvania, during the fiscal year ended June 30, 1881, Major S. C. Lyford, Ordnance Department, commanding.

*Appendix* 13.—Experiments with small-arms having varying length and weight of barrels and charges of powder and bullets, by Capt. John E. Greer, Ordnance Department.

*Appendix* 14.—Report on fabrication of centers for paper targets at Rock Island Arsenal, Illinois, by Major D. W. Flagler, Ordnance Department.

*Appendix* 15.—Description of harness manufactured at Rock Island Arsenal, Illinois, for the Laidley cavalry forge, by Major D. W. Flagler, Ordnance Department.

*Appendix* 16.—Physical properties of Ulster tube-iron, by Lieut. C. W. Whipple, Ordnance Department.

*Appendix* 17.—Long-range firing, being a continuation of Appendix 25, Report of 1880.

*Appendix* 18.—Report on a telemeter sight invented by Capt. Luigé Folta, Italian artillery, by Capt. John E. Greer, Ordnance Department.

*Appendix* 19.—Report on the inspection of contract small-arm ammunition, by Capt. Henry Metcalfe, Ordnance Department.

*Appendix* 20.—Report on the geology of the high plateaus of Utah, by Capt. C. E. Dutton, Ordnance Department.

*Appendix* 21.—Report on the Spencer line-throwing gun for life-saving purposes, by Lieut. D. A. Lyle, Ordnance Department.

*Appendix* 22.—The practical application of Bartlett's formulas to problems in gun construction, by Capt. George W. McKee, Ordnance Department.

*Appendix* 23.—Rational and practical ballistics, translated and adapted to the English system of weights and measures, by Lieut. O. B. Mitcham, Ordnance Department.

*Appendix* 24.—Report on feed-guides for machine-guns, and method of packing the ammunition for transportation, by Capt. John E. Greer, Ordnance Department.

*Appendix* 25.—Report on the Hunt life-saving projectile, by Lieut. D. A. Lyle, Ordnance Department.

*Appendix* 26.—Report on sponge, sponge-cover, and cartridge bag for the life-saving apparatus, by Lieut. D. A. Lyle, Ordnance Department.

*Appendix* 27.—Report on the manufacture of the "Mills" spurs and straps, by Lieut. L. L. Bruff, Ordnance Department.

*Appendix* 28.—Reports on experimental cartridges containing seventy and eighty grains powder and five hundred grains of lead, by Capt. John E. Greer, Ordnance Department.

*Appendix* 29.—Report on prism range-finders, by Lieut. A. H. Russell, Ordnance Department.

*Appendix* 30.—Report on pack outfit for Hotchkiss breech-loading mountain gun, by a board consisting of Captains R. P. Hughes, Third Infantry, and O. E. Michaelis, Ordnance Department.

*Appendix* 31.—Report of practice with the Hotchkiss, Gatling, and Gardner machine-guns, by Capt. E. B. Williston, Second Artillery.

*Appendix* 32.—Description of a proposed 3.5-inch breech-loading rifle, by Capt. George W. McKee, Ordnance Department.

*Appendix* 33.—Report on comparative merits of shells in aiming drill, by Lieut. C. C. Morrison, Ordnance Department.

*Appendix* 34.—Trajectory of a projectile *in vacuo*, by Capt. John E. Greer, Ordnance Department.

*Appendix* 35.—Report on files, by Lieut. D. A. Lyle, Ordnance Department, and S. W. Porter, master armorer at the National Armory.

*Appendix* 36.—Showing stations and duties of the officers of the Ordnance Department on the 1st of October, 1881.

REPORTS OF THE CONSTRUCTOR OF ORDNANCE.

*Appendix* 37.—Construction of an 11-inch breech-loading chambered rifle.

*Appendix* 37[a].—Construction of an 11-inch muzzle-loading chambered rifle.

*Appendix* 37[b].—Construction of an 8-inch breech-loading chambered rifle.

*Appendix* 37[c].—Construction of three 3.20-inch breech-loading chambered rifles.

*Appendix* 37[d].—Construction of carriage for 3.20-inch rifles.

*Appendix* 37[f].—Progress report on 12-inch breech-loading chambered rifles.

*Appendix* 37[g].—Progress report on 12-inch breech-loading chambered rifle howitzer.

*Appendix* 37[h].—Progress report on plant for fabrication of 12-inch rifles.

*Appendix* 37[i].—Report on tests of Firth's steel.

*Appendix* 37[k].—Progress report on cannon powder.

REPORTS OF THE ORDNANCE BOARD.

*Appendix* 38.—Proper mode of packing gunpowder.

*Appendix* 38[a].—Continued test of 8-inch breech-loading rifle, No. 1.

*Appendix* 38[b].—3.20-inch breech-loading chambered rifles.

*Appendix* 38[c].—11-inch muzzle-loading chambered rifle, No. 2.

*Appendix* 38[d].—Hotchkiss single and triple wall shells.

*Appendix* 38[f].—Hotchkiss mountain gun.

I have the honor to be, very respectfully, your obedient servant,

S. V. BENÉT,

*Brigadier-General, Chief of Ordnance.*

To the HON. SECRETARY OF WAR.

# APPENDIX 1.

***Statement of principal articles procured by fabrication at the arsenals during the fiscal year ended June* 30, 1881.**

## CLASS II.

13 carriages for Gatling guns.
1 ammunition cart for Gatling gun.

## CLASS III.

4 breech sights for 8-inch rifle.
4 braces for elevating arcs.
2 carrying bars.
74 chocks, iron wheel, right and left.
51 elevating arcs and indices.
4 fuse wrenches.
12 fuse plug wrenches for metallic plugs.
1 front sight seat.
50 gunners' haversacks for 8-inch rifle.
11 gun covers for Gatling guns.
99 handspikes, maneuvering.
50 handspikes, front.
50 handspikes, rear.
50 handspikes, recoil check.
12 handspikes, shod, for barbette carriages.
28 handspikes, trail, for field guns.
45 sets of harness for Laidley forge cart (2 horses).
3 sets of harness for Hotchkiss mountain gun.
250 harness bags.
4 muzzle covers and straps.
25 muzzle or front sights.
3 pass boxes.
29 pointing sights and arcs.
14 pouches for Quinan sights.
61 pinch bars.
2 priming wires, field guns.
50 priming wires, siege and garrison guns.
8 Quinan sights.
25 rear sights and sockets.
3 rear sights for Hotchkiss mountain gun.
4 rammers and staves for 8-inch rifle.
52 shot hooks.
54 shot carrying bars.
8 sponge covers for 3-inch rifle.
50 sponges and rammers for 8-inch rifle.
4 sponges and rammers for 12-pounder gun.
22 sponges and rammers for 10-pounder Parrott gun.

10 sponges and rammers for 3-inch wrought-iron rifled gun.
5 sponges and staves for 8-inch rifle.
54 thumbstalls.
1 tompion for 12-pounder siege gun.
3 tompions for 4.5-inch siege gun.
2 tompions for 24-pounder Coehorn mortar,
16 tompions for 8-inch gun.
1 tompion for 8-inch mortar.
5 tompions for 10-inch gun.
1 tompion for 10-inch mortar.
3 tompions for 15-inch Rodman gun.
50 tube pouches for 8-inch rifle.
5 vent covers.
39 vent pieces.

## Class V.

999 shells and cases for Hotchkiss mountain gun, caliber 1.65-inch, filled and fixed.
2,000 shells and cases for Hotchkiss revolving cannon, caliber 1.50-inch, filled and fixed.

## Class VI.

10,000 Springfield carbines, caliber .45.
14,863 Springfield rifles, caliber .45.
151 Springfield rifles, long range, caliber .45.
1,014 Springfield rifles with rod bayonet, caliber .45.
500 Springfield rifles, cadet, caliber .45.
1,000 Hotchkiss navy rifles, caliber .45.
2 shot guns.
100 cavalry officers' sabers.
1,002 hunting knives.

## Class VII.

### INFANTRY EQUIPMENTS.

1,001 bayonet scabbards, steel, hook attachment.
11,761 bayonet scabbards, steel, Hoffman's attachment.
7,373 blanket bags with coat straps.
7,373 blanket bag shoulder straps.
5,514 canteens.
6,104 canteen straps and hooks.
8,900 cartridge belt plates.
1 cartridge belt and buckle with D rings.
674 clothing bags.
81 frogs, sliding, for non-commissioned officers' swords.
1,150 frogs for bayonet scabbards.
4,960 gun slings, lengthened.
521 haversacks.
1,000 haversack straps.
450 hook straps for carrying braces.
25 knapsacks, Hoffman's pattern.
7,410 McKeever cartridge boxes.
1,080 pairs great coat straps.
1,002 scabbards for hunting knives.
10,000 waist belts and plates, O. M. No. 19.
1,540 waist belt plates, non-commissioned officers.

CAVALRY ACCOUTERMENTS.

1,800 carbine slings.
12 pistol cartridge pouches.
503 pistol holsters.
2 saber belts.
602 saber belt plates.

APPENDAGES

250 brush wipers.
406 bullet moulds, round ball.
43,518 headless shell extractors.
10,419 jointed ramrods.
1,013 wipers for rod bayonets.
1,130 wiping rods, wood.
35,327 screw-drivers.

HORSE EQUIPMENTS

2 bridles, curb, cavalry.
50 cincha straps.
35 girth billets.
4,700 hair cinchas.
900 halter-straps.
8,450 halters and straps.
1,000 horse covers.
2,499 lariats.
2,050 picket pins.
502 saddles.
2,150 saddle bags, dyed duck.
2,850 saddle bags, leather.
500 spurs and straps.
2,070 side lines.
50 surcingles.
1 watering bridle.

CLASS VIII.

3,000 blank cartridge bags, ½ pound.
1,200 blank cartridge bags, 2 pound.
3,596 cartridge bags, 10-pounder gun.
11,268 cartridge bags, 3-inch gun.
10,000 cartridge bags, 12-pounder mountain howitzer.
21,984 cartridge bags, 12-pounder field gun.
9,250 cartridge bags, 6-pounder field gun.
150 cartridge bags, 11-inch rifle.
1,002,000 carbine ball cartridges, caliber .45.
2,561,153 rifle ball cartridges, caliber .45.
10,000 rifle ball cartridges, long range, caliber .45.
3,000 rifle ball cartridges, 500-grain bullet, caliber .45.
309,130 rifle and carbine ball cartridges, caliber .45, solid head, reloading, model 1881.
552,510 revolver ball cartridges, caliber .45.
290,500 bullets, caliber .45.
78,900 rifle bullets, lubricated, 500 grain, caliber .45.

1,163,100 round bullets, caliber .45.
430 cartridges for shot guns.
107,000 blank cartridges, caliber .58.
319,100 rifle and carbine blank cartridges, caliber .45.
105,384 blank revolver cartridges, caliber .45.
124,660 friction primers.
2,000 electric primers.
400 paper fuses, 25 seconds to the inch.
25 Woodbridge fuses.

### Class IX.

377 blocks.
18 blocks, half.
17 blocks, quarter.
2 blocks, snatch.
8 chains, iron.
1 capstan and bars.
25 chocks, roller.
50 chocks, wheel.
1 cradle, 15-inch gun.
3 derricks.
4 gin blocks, iron, double and treble.
2 hand carts.
109 Laidley revolving targets.
18 hand carts, covered.
11 platforms for mortars.
7 platforms for siege guns.
30,000 paper centers for targets.
3,265,000 pasters.
36,069 paper targets.
2 range finders, Weldon.
28 rollers, long.
16 rollers, short.
24 shifting planks.
1 shears for 15-inch gun.
39 shot beds.
240 shot marks.
20 skids.
1 sling wagon, Laidley.
1 set of velocity targets.
2 trunnion chains.

### Class X.

4 shafts for Hotchkiss mountain carriage.
5 keys and stay-pins.
1 key-bolt.
2 pounds wheel nails.
3 parts of Laidley cavalry forge.
4 parts of Hotchkiss mountain carriage.
1 pole for field carriage.
24 spokes for wheels.
60 felloes for wheels.
4 pole pads.
2 pairs pole straps.
13 rammer heads for 3-inch guns.

12 woolen sponges for field guns.
560 sabots for 15-inch shells.
340 tin straps for 15-inch shells.
8 barrels for Springfield rifles, caliber .45.
57 bayonets for cadet rifles, caliber .50.
107,889 spare parts for Springfield rifles, caliber .45.
185 spare parts for Hotchkiss navy rifles.
45 parts of swords.
25 pistol grips.
48 stocks for Springfield rifles, caliber .45.
34,000 iron and brass buckles.
1,880 canteen covers.
2,548 fasteners for side lines.
1,203 brass hooks for bayonet scabbards.
350 hook straps.
2,622 hooks for lariats.
3,000 hooks and straps for canteens.
100 halter hooks.
100 double S halter hooks.
50 halter bolts.
159 halter rings.
6,300 halter straps.
1,000 halter strap swivels.
3,500 meat cans.
170 guard plate ovals.
124 parts of horse equipments.
1,000 saddle bag studs.
500 swivels for side lines.
500 spring snaps.
5,000 staples for rings.
216 artillery surcingles.
5,990 tin cups.
30,975 cartridge bags, empty, various.
65,200 cartridge shells, caliber .45.
759,000 cartridge primers.
260 time fuse plugs.
7 parts of gins.
20 springs for Laidley targets.
35 shot mark staves.

MISCELLANEOUS.

1,288 arm chests.
4 axe handles.
2 benches.
8 quarts browning mixture.
2 cedar cases.
101 chamois skin cases.
1 copy press stand.
195 grates for heating stoves.
3,502 pounds harness oil.
12 copper hoops for powder barrels.
1 hydroscope.
4 iron gutters.
143 laboratory articles.
115 gallons lacquer.

250 boxes leather blacking ingredients.
2 lightning arresters.
4 lockers.
1,000 pounds lubricant for bullets.
2,420 packing boxes, wood.
22 packing boxes, tin.
6,119 pounds paint, various.
3 pasteboard boxes.
111 portable arm racks.
110 pounds putty.
96 riveting irons.
438 pounds scouring and polishing material.
66 pounds sealing wax.
1,878 small arm ammunition boxes.
2 steps.
52 strainers for lubricating bullets.
212 stove feet.
3 tables.
1 target mask and screen.
2 target plates.
3 target cameras.
3,426 tin cans.
1 vernier wheel.
50 pounds wheel grease.
4 wooden tubs.

TOOLS.

109 augers.
1 annealing furnace.
243 armorer's mills.
1 armorer's tool chest.
1 belt shifter.
43 bits.
261 brushes.
2 bookcases.
1 bullet trimming machine.
2 burning irons.
500 button sticks.
9 caliber plugs.
1 cartridge burring machine.
4 cartridge trimming machines.
1 cartridge primer inserting machine.
2 cartridge stamping machines.
256 cast-iron army stoves (for wood and coal).
208 chisels.
18 cold chisels.
17 counterborers.
248 dies, various.
1 desk.
1 diameter calipers.
1 die stock.
898 drills.
1 drill jig.
1 drop hammer.
4 electric switches.
2 firing rests.

22 forgings.
1 former for electric primer box.
300 gas checks.
68 gauges, assorted.
6 gauges, eccentric head.
4 glue pots.
3 handles.
125 hand tools for reloading cartridges.
8 ice boxes.
111 iron bolts.
4 ladders.
2 leather aprons.
1 loading tube.
1,000 labels.
3 mallets.
1 milling machine.
16 miscellaneous office articles.
2 pans.
7 patterns.
203 powder chargers.
1 pressure piston.
800 pressure disks.
1 pressure scale.
1 pressure dynamometer.
83 primer extractor pins.
5 primer extractors.
340 proving plugs.
11 punches.
63 punching blocks, lead.
124 rods for stoves.
250 reloading funnels.
101 rotary files.
1 saddler's horse.
1 signal flag.
13 shoeing knives.
12 slickers, steel.
8 stamps (figures).
2 taps.
1 tap wrench.
12 tool bags.
48 tools, primer box.
3,911 tools for current service (various).
1 wheelbarrow.
6 wire scratch brushes.
52 wrenches.
1 yoke for harness.

## APPENDIX 2.

*Statement of principal articles procured by purchase at the arsenals during the year ending June* 30, 1881.

### Class II.

6 carriages for Gardner machine guns.
4 carriages for Gatling guns, 10 barrels, long, caliber .50.
10 carriages for Hotchkiss mountain guns, caliber 1.65.
1 carriage and limber for breech-loading rifle, caliber 3.2 inches.

### Class III.

1,620 feed cases for Gardner machine guns.
316 feed cases for Gatling guns, caliber .50.
10 sets of implements for Hotchkiss mountain guns, caliber 1.65 inches.
200 paulins, 12 by 15 feet.

### Classes IV and V.

40 11-inch Butler cored shot.
200 4.5-inch Butler shot.
200 4.5-inch Butler shell.
200 3-inch Butler shot.
200 3-inch Butler shell.
15 8-inch Butler shell.
50 Butler's solid shot, 11-inch rifle.

### Class VI.

1,000 Colt's revolvers, caliber .45.

### Class VII.

5,000 saddle blankets.
988 felt saddle cloths.
40,026 woven cartridge belts.
5,138 curry combs.
10,000 Mills' cartridge belt plates.

### Class VIII.

55,000 pounds musket powder.
105,000 pounds hexagonal powder.
300,000 rifle ball cartridges, caliber .50.
450 Hotchkiss percussion fusee.

### CLASS X.

| | |
|---|---|
| 500 | Whitman saddle trees. |
| 1,246,250 | Winchester cartridge primers. |
| 150 | sabots for 11-inch muzzle loading rifle. |
| 60 | sabots for 3.20-inch breech loading rifle. |

### MISCELLANEOUS.

| | |
|---|---|
| 10,000 | yards cotton cloth, 72 inches. |
| 225 | yards burlaps. |
| 320 | pounds sash cord. |
| 2,756 | pounds cotton waste. |
| 3,665 | yards cotton duck. |
| 9,068 | pounds rope. |
| 1,437 | pounds thread. |
| 534 | pounds twine. |
| 8,004 | yards webbing. |
| $851\frac{1}{4}$ | yards cotton twills. |
| 4,200 | pounds bran. |
| 35,000 | pounds hay. |
| 28,000 | pounds meal. |
| 64 | bushels meal. |
| 16,000 | pounds oats. |
| $929\frac{13}{32}$ | bushels oats. |
| 60,535 | pounds straw. |
| 1 | barrel rye flour. |
| 6 | barrels salt. |
| 2,900 | pounds sheet brass. |
| $1,520\frac{3}{8}$ | pounds brass castings. |
| $52,781\frac{1}{2}$ | pounds iron castings. |
| $136,119\frac{1}{2}$ | pounds sheet copper. |
| 133 | pounds bar copper. |
| 56 | pairs hinges. |
| 7,312 | pounds bar iron. |
| 3,437 | pounds plate iron. |
| 20,780 | pounds nails. |
| 1,320 | gross screws. |
| 304,821 | pounds gun steel. |
| 1,000 | pounds cast steel. |
| 1,707,000 | iron tacks. |
| $44\frac{1}{2}$ | pounds iron tacks. |
| 125 | papers copper tacks. |
| 3,000 | copper tacks. |
| 700 | pounds block tin. |
| 2 | boxes sheet tin. |
| 12 | papers glazier's points. |
| 62 | pounds brass wire. |
| $1,003\frac{1}{2}$ | pounds copper wire. |
| 1,000 | feet Kerite covered wire. |
| 250 | feet platinum wire. |
| $30\frac{3}{4}$ | pounds steel wire. |
| 171 | pounds iron washers. |
| 560 | pounds iron nuts. |
| 100 | pounds soldering wire. |
| 5,317 | feet iron pipe. |

37 cocks, valves, &c.
1,872 gas fittings.
96 wrought iron I beams.
4 wrought iron channel beams.
15,912 pounds cast iron columns.
39,513 pounds iron roof trusses.
522 pounds cast iron doors and frames.
46,279$\frac{3}{4}$ square feet black bag leather.
1,101$\frac{1}{4}$ square feet bellows leather.
395 feet belting leather.
1,012$\frac{3}{4}$ square feet bridle leather.
4,928 sides bridle leather.
300 pounds buff leather.
41,135 square feet collar leather.
23,504 pounds harness leather.
2 sides harness leather.
40 sides lace leather.
400 feet lace leather.
4,885 balls black wax.
150,067 feet boards.
21,039 feet plank.
2,872 feet timber.
10,000 bricks.
3 barrels cement.
43 boxes window glass.
600 feet window glass.
50 bushels lime.
130 posts.
857 feet curb-stone.
144 brooms.
252 pounds candles.
30,949 bushels charcoal.
12 chamois skins.
1,519$\frac{55}{2240}$ tons anthracite coal.
1,242$\frac{1720}{2240}$ tons bituminous coal.
25$\frac{1}{3}$ reams emery and crocus cloth.
80 quires emery paper.
5,100 pounds emery.
48$\frac{1}{2}$ reams sand paper.
2,007$\frac{1}{2}$ pounds soap.
25 barrels soap.
106 pounds sponge.
450 papers tripoli.
13 emery wheels.
23 pounds rottenstone.
4,219$\frac{1}{2}$ gallons gasoline.
5 pounds pumice stone.
8 cords pine wood.
1,200 pounds wrapping paper.
1,000 feet red tape.
8,256 envelopes.
12 star copying pads.
18 Sisson's binders.
4 reams shoe paper.
12 pencil sharpeners.
1 set rollers for letter press book.

19 gross steel pens.
6 gross quill pens.
34½ reams writing paper.
27 dozen pencils.
18 gross rubber bands.
12 boxes adhesive seals.
7 pounds sealing wax.
15 quarts writing ink.
12 bottles carmine ink.
24 ink erasers.
288 thumb tacks.
5 pounds Davidson's rubber.
48 yards tracing cloth.
6 sticks India ink.
2 reams printing paper.
1,600 shipping tags.
60 boxes gum labels.
5,000 china cards.
24 rubber penholders.
144 pencil point protectors.
5 pounds banker's pins.
2,000 Heyl's fasteners.
1,000 eyelets.
20 pans N. & N. vermilion.
1 bottle Chinese white.
12 spring files.
24 bottles pounce.
12 plain wire files.
12 ink erasing pencils.
1,000 bristle board cards.
21,844 pounds sulphuric acid.
4½ gallons carbolic acid.
500 pounds muriatic acid.
373½ gallons alcohol.
22½ pounds beeswax.
50 gallons benzine.
150,000 pounds bone.
100 pounds borax.
47 pounds chalk.
600 pounds glue.
24 cans concentrated lye.
500 pounds nitric acid.
200 pounds mercury.
100 pounds chlorate of potash.
10 pounds cyanide of potash.
5,500 pounds sal soda.
4,000 pounds silicate of soda.
125 pounds sulphate of copper.
10 barrels coal tar.
1,997 pounds potash, Montreal.
25 pounds sulphate of iron.
1 pound carmine.
96 pounds chrome yellow.
28 pounds ivory black.
737 pounds lampblack.
45 gallons lacquer.

175 pounds litharge.
19,983 pounds white lead.
450 pounds red lead.
100 pounds dry lead.
10 gallons castor oil.
298½ gallons cod oil.
128 quarts cosmoline oil.
102 gallons headlight oil.
100 gallons kerosene oil.
2,766$\frac{1}{4}$ gallons lard oil.
2,143$\frac{7}{16}$ gallons linseed oil.
604½ gallons neat's-foot oil.
1 gallon olive oil.
3,518½ gallons sperm oil.
49½ gallons valvoline.
550 pounds black paint.
125 pounds green paint.
500 pounds lead-color paint.
4,570 pounds metallic paint.
1,600 pounds olive paint.
275 pounds red paint.
32 pounds Prussian blue.
300 pounds putty.
225 pounds shellac.
35 pounds stone yellow.
1,345$\frac{1}{12}$ gallons turpentine.
10 pounds Tuscan red.
60 pounds burnt umber.
100 pounds Venetian red.
49 pounds vermilion.
10 gallons copal varnish.
60½ gallons coach varnish.
58 gallons Japan varnish.
104 gallons varnish, patent drier.
149 pounds varnish, patent drier.
20 pounds sienna.
990 pounds whiting.
1,950 pounds yellow ocher.
100 pounds zinc.
62 packing boxes.
1,385 tin boxes.
30,000 pounds straw boards.
50 tin cans.
48 drinking cups.
350 pounds wheel grease.
1 set post harness.
300 feet linen hose.
2,924 pounds Japan wax.

TOOLS.

1 lead furnace for heating steel.
1 automatic cut-off steam engine.
1 gravimetric density balance.
1,062 brushes.
100 pounds chalk line.

| | |
|---|---|
| 2 | dozen chalk lines. |
| 188 | twist drills. |
| 1,522 | handles. |
| 264 | knives. |
| 76 | oil stones. |
| 250 | priming tools. |
| 2,161 | tools, various. |
| 60 | utensils, various. |
| 1 | milling machine. |
| 2 | grinding machines. |
| 1 | screw machine. |
| 1 | Spencer recapper. |
| 1 | annealing apparatus. |
| 1 | water heater and pump. |
| 1 | machine for hardening steel. |

## APPENDIX 3.

*Statement of ordnance, ordnance stores, &c., issued to the military establishment, exclusive of the militia, during the fiscal year ended June* 30, 1881.

### Class I.

4 Lowell battery guns.
3 Gardner machine guns.
7 Gatling guns, caliber .45, 10 long barrels.
2 Gatling guns, caliber .45, 5 short barrels.
9 3-inch rifled guns.
6 4.5-inch siege guns.
2 light 12-pounder guns.
1 8-inch Rodman gun.
1 10-inch Rodman gun.
2 24-pounder Coehorn mortars.
2 10-inch siege mortars.
3 13-inch siege mortars.

### Class II.

2 tripods for short barrel Gatling gun.
2 ammunition carts for Gatling gun.
1 Gatling battery cart.
6 carriages and limbers for long-barrel Gatling gun.
3 carriages and limbers for Gardner machine gun.
4 carriages and limbers for Lowell battery gun.
8 carriages and limbers for 3-inch rifle.
1 carriage without wheels for 3-inch rifle.
6 caissons and limbers for 3-inch rifle.
2 6-pounder carriages without limbers.
2 12-pounder carriages and limbers.
5 4.5-inch siege carriages and limbers.
2 8-inch siege howitzer carriages and limbers.
1 15-inch top carriage.
2 24-pounder mortar beds.
1 8-inch siege mortar bed.
3 10-inch siege mortar beds.
19 Laidley cavalry forges.
2 portable cavalry forges.
1 traveling forge A and limber.
1 limber for traveling forge.
1 battery wagon C and limber.
1 mortar wagon and limber.

### Class III.

4 elevating arcs and braces, barbette.
28 harness bags.

6 elevating bars.
4 pinch bars.
4 shot-carrying bars.
14 baskets for mortar implements.
4 pass boxes.
2 wooden forge buckets.
5 iron sponge buckets.
4 wooden sponge buckets.
4 iron tar buckets.
52 gutta-percha water buckets.
4 leather water buckets.
2 papier-machè water buckets.
4 iron wheel chocks, left.
4 iron wheel chocks, right.
10 powder funnels.
10 gunners' gimlets, field.
2 fuse gouges,
33 maneuvering handspikes, wood.
1 handspike for mountain howitzer.
20 shod handspikes.
27 trail handspikes.
2 sets harness, 2 horses, for Gatling cart.
2 sets harness, 1 horse for Hotchkiss mountain gun.
34 sets harness, 2 horses, for Laidley cavalry forge.
2 sets harness for 2 wheel-horses.
12 gunners' haversacks.
2 pendulum hausses, 6 pounder.
4 pendulum hausses, 12-pounder.
14 pendulum hausses, 3-inch.
3 shell hooks.
6 tow hooks.
4 indices and pointers.
2 ladles and staves.
4 common lanterns.
6 dark lanterns.
34 globe lanterns.
2 magazine lanterns.
123 lanyards for friction primers.
11 fuse mallets.
2 powder measures.
6 paulins, 5 by 5 feet.
14 paulins, 6 by 10 feet.
6 paulins, 8 by 10 feet.
75 paulins, 12 by 15 feet.
2 paulins, 20 by 30 feet.
9 gunners' pincers.
4 plummets.
3 gunners' pouches.
8 pendulum hausse pouches.
12 sight pouches.
4 tube pouches.
25 prolonges.
1 gunner's quadrant, brass.
8 rammers and staves, 4.5-inch.
2 fuse reamers.
7 fuse saws.

4 fuse setters.
5 scrapers for mortar.
6 breech sights, 4.5-inch.
6 front sights, 4.5-inch.
8 Quinan front sights, with seats and beds.
8 Quinan rear sights and seats.
42 gunners' sleeves.
3 spatulas.
12 cannon spikes.
4 sponge covers, 6-pounder.
36 sponge covers, 3 inch.
4 sponge covers, 12-pounder.
2 sponge covers, mountain howitzer.
12 sponge covers, 30-pounders.
2 sponges and rammers, 6-pounder.
58 sponges and rammers, 3-inch.
55 sponges and rammers, 12-pounder.
18 sponges and rammers, mountain howitzer.
1 sponge and rammer, 15-inch.
8 sponges and staves, 4.5-inch.
2 telescopes for Hotchkiss revolving gun.
53 thumbstalls.
1 tompion, 6-pounder.
10 tompions, 3-inch.
3 tompions, 4.5-inch.
3 tompions, 12-pounder.
2 tompions, 24-pounder mortar.
16 tompions, 8-inch gun.
1 tompion, 8-inch mortar.
5 tompions, 10-inch gun.
1 tompion, 10-inch mortar.
8 tompions, 15-inch.
31 vent covers.
35 vent pieces.
10 vent punches.
4 wipers for mortar.
20 priming wires, field.
12 priming wires, siege.
23 worms and staves, field.
4 worms and staves, siege.
4 fuse wrenches.
12 fuse plug wrenches.

*Implements for long-barrel Gatling gun, caliber* .45.

198 feed cases.
4 clamps for worm gear.
4 gun covers.
3 drifts.
4 shell drivers.
4 headless shell extractors.
2 wiping-rod handles.
8 trail handspikes.
4 oscillators.
4 brass wiping rods.
4 lock screw drivers.

4 small screw drivers.
4 T screw drivers.
4 adjusting screw wrenches.
4 pin wrenches.
4 rear guide nut wrenches.

*Implements for short-barrel Gatling gun, caliber .45.*

212 feed cases.
5 gun covers.
2 shell drivers.
2 brass wiping rods.
2 lock screw drivers.
2 small screw drivers.
2 T screw drivers.
2 rear guide nut wrenches.
3 gun covers, Gatling gun, caliber .50.
10 gun covers, Gatling gun, caliber 1-inch.
1 gun cover, Hotchkiss revolving gun, caliber 1.5-inch.

*Implements for Lowell battery gun.*

20 ammunition boxes.
4 oil cans.
2 headless shell extractors.
8 handspikes.
4 locks.
4 firing pins.
2 wiping rods.
2 T screw drivers.
4 firing-pin springs.
4 main springs.
4 grind tools.
8 bronze feed tubes.
1,000 tin feed tubes.

*Implements for Gardner machine gun.*

810 feed cases.
3 breech casing covers.
18 drifts.
3 shell drivers.
1 extractor
2 headless shell extractors.
3 feed guides.
3 hammers.
5 trail handspikes.
1 firing pin.
3 wiping rods.
3 T screw drivers.
2 firing-pin springs.
3 lock wrenches.

CLASSES IV AND V.

1,125 1.5-inch Hotchkiss projectiles.
1,400 1.65-inch Hotchkiss projectiles.

212 3-inch shot.
816 3-inch shell.
347 3-inch case.
130 3-inch canister.
48 12-pounder gun shot.
296 12-pounder gun shell.
296 12-pounder gun case.
296 12-pounder gun canister.
234 12-pounder howitzer shell.
108 12-pounder howitzer case.
216 12-pounder howitzer canister.
30 24-pounder shell.
150 30-pounder shot.
184 4.5-inch shot.
334 4.5-inch shell.
50 4.5-inch shrapnel.
220 8-inch shot.
10 8-inch shell.
120 8-inch mortar shell.
10 10-inch shell.
120 10-inch mortar shell.

## Class VI.

490 Hotchkiss magazine carbines, caliber .45.
1,505 Springfield carbines.
1,708 Springfield rifles.
124 Springfield rifles, long range.
900 Springfield rifles with rod bayonets.
938 Colt's revolvers.
6 Colt's revolvers, caliber .44.
210 Schofield's Smith & Wesson revolvers.
9 double-barrel breech-loading shot guns.
19 artillery sabers.
362 cavalry sabers.
20 artillery swords.
50 musician's swords.
64 non-commissioned officer's swords.
6 officer's swords.
31 trowel bayonets.
900 hunting knives.

## Class VII.

32 artillery saber belts.
32 artillery saber-belt plates.
344 carbine cartridge pouches.
2,325 carbine slings.
2,066 carbine sling swivels.
117 pistol cartridge pouches.
3,556 pistol holsters.
901 cavalry saber belts.
907 cavalry saber belt plates.
386 cavalry saber knots.
2,795 blanket bags.
6,055 clothing bags and straps.

6,053 cartridge belts.
139 non-commissioned officer's sword belts and plates.
3,408 private's waist belts.
2,197 cartridge boxes.
38 cartridge boxes, No. 1.
81 cartridge boxes, No. 2.
572 carrying braces.
21 shoulder braces.
6,186 canteens and straps.
4,022 canteens.
8,166 meat cans.
8,276 tin cups.
11,556 forks.
216 sliding frogs.
9,394 haversacks and straps.
100 rifle holsters, Willcox.
9,735 knives.
3,666 cartridge belt plates.
3,407 waist belt plates.
360 cap pouches, altered.
2,203 steel bayonet scabbards, Hoffman attachment.
1,007 steel bayonet scabbards and frogs, hook attachment.
49 trowel bayonet scabbards.
960 hunting knife scabbards or sheaths.
698 intrenching tool scabbards.
3,438 gun slings.
9,654 spoons.
2,944 pairs blanket bag shoulder straps.
237 sets blanket bag coat straps.
1,778 blanket and coat straps.
6 brace yoke and stay straps.
52 stay or steady straps.
90 valises.
4 scratch brushes.
8 cappers for shot guns.
9 chargers for shot gun.
40 powder chargers, caliber .45.
1 wad cutter.
3,528 headless shell extractors.
74 rifle ball molds, 4 balls.
597 tumbler punches.
1 Osgood's cartridge reloader.
6 rods for shot gun.
109 pistol wiping rods.
276 wooden wiping rods.
265 screw-drivers.
687 pistol screw-drivers.
1 loading tube.
131 spring vises.
419 brush wipers and thongs.
900 wipers for rod bayonets.
5,921 nose bags.
3,067 saddle bags.
394 artillery saddle blankets.
5,775 cavalry saddle blankets.
2,124 curb bridles.

2,115 watering bridles.
7,163 horse brushes.
3,053 hair cinchas.
468 saddle cloths.
5,097 curry combs.
1,434 horse covers.
426 cruppers.
4 leather girths.
689 linen girths.
5,844 halters and straps.
6,059 lariats.
4,402 side lines.
665 links.
2,909 picket pins.
207 forage sacks.
1,319 saddles.
70 saddles, Whitman horn tree.
255 carbine sockets.
4,770 spurs.
4,704 spur straps.
4,003 surcingles.

## Class VIII.

1,304,000 carbine ball cartridges.
2,332,231 rifle ball cartridges.
17,000 rifle ball cartridges, reloading.
227,000 rifle blank cartridges.
197,912 revolver ball cartridges.
2,850 revolver ball cartridges, reloading.
1,400 revolver ball cartridges, caliber .44.
56,800 revolver blank cartridges.
32,000 metallic blank cartridges, cadet.
1,000 musket blank cartridges, caliber .58.
5,000 rifle blank cartridges, caliber .50.
6,430 cartridges for breech-loading shot gun.
423,119 round balls.
1,263,331 rifle bullets.
28,500 revolver bullets, lubricated.
5,638 caps for shot-gun cartridges.
3,000 charges, powder.
2,265,030 small arm cartridge primers.
10,000 cartridge shells.
24,000 paper wads.
8,200 blank cartridges, mountain howitzer.
18,700 blank cartridges, 12-pounder gun.
8,700 blank cartridges, 6-pounder gun.
23,059 blank cartridges, 3-inch gun.
4,885 blank cartridges, ½-pound charge.
95,000 lubricating discs.
675 assorted fuses.
50 pounds slow match.
52 yards slow match.
17,700 pounds cannon powder.
23,000 pounds hexagonal powder.
2,000 pounds sphero-hexagonal powder.

4,700 pounds mammoth powder.
1,205 pounds mealed powder.
22,045 pounds mortar powder.
12,779 pounds musket powder.
73 pounds sporting powder.
3,000 electric primers.
110,375 friction primers.
2 grommet wads.

### CLASS IX.

7 fencing bayonets.
3 double blocks.
18 half blocks.
17 quarter blocks.
1 single block.
2 snatch blocks.
2 tackle blocks.
5 treble blocks.
26 whole blocks.
232 wood blocks.
120 wood blocks, 8 by 10 inches.
39 shot beds.
454 marksmen's buttons.
1 capstan and bar.
5 hand carts.
3 sling carts.
8 sling chains.
2 trunnion chains.
25 roller chocks.
48 wheel chocks.
1 cradle for moving heavy gun.
601 bull's eyes and centers.
2 gin falls.
2 Weldon range finders.
14 danger flags.
2 field and siege gins.
3 garrison gins.
14 gin handspikes.
6 hydraulic jacks.
1 lifting jack.
1 Laidley gun lift.
11 shot marks.
130 4-inch shot marks.
137 6-inch shot marks.
29 12-inch shot marks.
4 fencing muskets, cadet.
2,400,000 pasters for targets.
22 shifting planks.
6 platforms, siege carriage.
10 platforms, mortar.
89 portable arm racks.
32 long rollers.
14 short rollers.
12 trace ropes.
1 shears, complete, for hoisting 15-inch gun.

28 skids.
10,200 paper targets.
1,166 paper targets, reduced size.
11,812 paper targets, A.
10,391 paper targets, B.
3,614 paper targets, C.
60 Laidley revolving targets.
44 intrenching tools.
69 transoms.
2 store trucks.
1 Laidley sling wagon.

CLASS X-I.

2 extractors for Gardner machine gun.
2 firing pins for Gardner machine gun.
4 firing-pin springs for Gardner machine gun.
4 locks for Lowell battery gun.
2 firing pins for Lowell battery gun.
2 firing-pin springs for Lowell battery gun.

CLASS X-II.

4 nave bands.
2 tire bands.
2 splinter bars.
20 tire bolts.
2 turn buckles.
20 ammunition chests.
1 caisson limber chest.
3 Hagadon limber chests for 3-inch rifle.
44 fellies.
13 stay-pin keys and chains.
2 pounds nails.
1 bronze nave for Laidley cavalry forge.
1 nut.
3 linchpins.
8 stay pins.
1 wind pipe for cavalry forge.
13 poles.
1 pole prop.
2 shafts for Hotchkiss mountain carriage.
60 spokes.
6 stakes for mortar wagon.
1 battery-wagon stock.
1 singletree with hooks.
44 washers and nuts.
16 linch washers.
13 wheels, complete.
1 wheel for Laidley cavalry forge.
3 pole yokes.

CLASS X-III.

12 artillery bridles.
3 collars.

50 halters.
1 hames.
26 rammer heads, 3-inch.
3 rammer heads, 6-pounder.
2 rammer heads, 12-pounder.
10 rammer heads, 12-pounder mountain howitzer.
16 sponge heads, 3-inch.
2 sponge heads, 12-pounder.
137 cold shut links.
552 bridle ornaments.
10 pole pads.
90 rosettes for artillery bridles.
12 woolen sponges.
131 woolen sponges, 3-inch.
33 woolen sponges, 6-pounder.
83 woolen sponges, 12-pounder.
16 woolen sponges, 4.5-inch gun.
44 woolen sponges, mountain howitzer.
20 woolen sponges, 8-inch.
32 woolen sponges, 10-inch.
12 woolen sponges, 42-pounder.
22 staves for sponges and rammers.
200 halter hitching straps.
24 hame straps.
14 pole straps.
4 lead traces.
1 wheel trace.
3 valises.
84 whips.

### CLASS X–IV AND V.

500 water caps for fuse plugs.
700 metallic fuse plugs.
430 sabots, 15-inch shell.
340 tin straps, 15-inch shell.

### CLASS X–VI.

*Parts of Springfield rifle.*

6 lower bands.
112 upper bands.
107 band springs.
1 barrel.
601 bayonets.
37 bayonet clasps.
46 bayonet clasp screws.
3 breech blocks.
15 breech block caps.
258 breech block cap screws.
5 breech screws.
258 bridles.
272 bridle screws.
128 butt plate screws.
35 cam latches.
369 cam latch springs.

782 ejector springs.
714 ejector spring spindles.
9 ejector studs.
379 extractors.
1,122 firing pins.
269 firing pin screws.
51 front sights.
204 grips.
50 guard bows.
20 guard bow nuts.
101 guard bow swivels.
33 guard bow swivel screws.
101 guard plates.
128 guard screws.
18 hammers.
12 hinge pins.
9 locks.
2 lock plates.
154 main springs.
46 main spring swivels.
30 main spring swivel rivets.
19 ramrods.
106 ramrod stops.
68 rear sights.
114 rear sight buckhorn plates.
10 rear sight bases.
10 rear sight base screws.
5 rear sight base springs.
15 rear sight leaves.
7,770 rear sight slide gibs.
130 rear sight slide plates.
908 rear sight slide screws.
100 rear sight centering pins.
5 rear sight joint pins.
114 rear sight slide blocks.
26 rear sight slide springs.
141 sears.
326 sear screws.
170 sear springs.
20 sear spring screws.
177 side screws.
100 side screw washers.
130 stocks, complete.
30 stocks, wood part.
47 tang screws.
115 thumb pieces.
100 tip screws.
100 tips for stacks.
12 trigger screws.
50 tumblers.
181 tumblers, swiveled.
324 tumbler screws.

*Parts of Springfield carbine.*

11 bands.
100 stacking bands.

302 barrels.
81 breech block cap screws.
10 breech screws.
9 bridles.
16 bridle screws.
100 butt plates.
200 butt plate covers.
100 butt plate screws.
6 cam latches.
117 cam latch springs.
100 cover friction springs.
100 cover springs.
100 cover stud pins.
206 ejector springs.
135 ejector spring spindles.
10 ejector studs.
61 extractors.
216 firing pins.
123 firing pin screws.
488 pistol grips.
579 front sights.
617 front sight pins.
59 guard bows.
22 guard bow nuts.
9 guard plates.
37 guard screws.
6 hammers.
61 hinge pins.
3 lock plates.
110 main springs.
6 main spring swivels.
10 main spring swivel rivets.
76 sears.
35 sear screws.
138 sear springs.
12 sear spring screws.
40 side screws.
66 rear sights, complete.
1,222 jointed ramrods.
6 rear sight base screws.
12 rear sight base springs.
6 rear sight leaves.
6 rear sight leaf slides.
45 stocks, complete.
163 stocks, wood part.
106 swivel bars.
6 swivel bar rings.
12 tang screws.
5 triggers.
10 trigger screws.
122 tumblers.
116 tumbler screws.

*Parts of Hotchkiss carbine and rifle.*

120 extractors.
5 cut-offs.

40 firing pins.
100 cartridge stop pins.
120 trigger pins.
410 jointed ramrods.
120 firing pin screws.
20 sear spring screws.
100 trigger spring screws.
100 bolt lock springs.
100 cut-off springs.
40 magazine springs.
120 mainsprings.
20 sear springs.
40 trigger springs.
2 stocks, wood part; carbine.
20 cartridge stops.
20 triggers.

*Parts of Colt's revolver.*

143 back strap screws.
18 bolts.
26 bolt screws.
172 center pins.
4 center pin bushings.
72 center pin catch screws.
26 center pin screws.
49 ejector heads.
56 ejector rods.
105 ejector springs.
29 ejector tubes.
96 ejector tube screws.
48 ejector tube springs.
52 firing pins.
52 firing pin rivets.
18 gate catches.
82 gate catch screws.
30 gate catch springs.
52 gate springs.
92 guard screws, long.
88 guard screws, short.
71 hammers.
8 hammer cams.
76 hammer screws.
40 hands.
66 hand springs.
100 mainsprings.
42 mainspring screws.
12 mainspring swivels.
3 recoil plates.
11 sear springs.
12 sear spring screws.
24 sear and stop bolt screws.
78 sear and stop bolt springs.
68 sear and stop bolt spring screws.
6 stocks.
50 stop bolt screws.
70 triggers.
60 trigger screws.

*Parts of Schofield's Smith and Wesson revolver.*

10 barrel catch screws.
11 barrel catch springs.
2 base pins.
14 cylinder catch cams.
8 cylinder catch screws.
10 extractors.
9 extractor springs.
8 extractor stems.
8 hand springs.
1 lifter.
8 mainsprings.
8 pawl springs.
10 stop pins.
10 stop springs.
19 stocks.
14 strain screws.
15 triggers.
8 trigger springs.
6 trigger spring pins.

*Parts of breech-loading double barrel shotgun.*

6 bridles.
12 bridle screws.
6 cones.
6 guard screws, front.
6 guard screws, rear.
2 locks, complete.
4 hammers.
6 lifter springs.
6 mainsprings.
6 mainspring swivels.
6 plungers.
6 sears.
8 sear springs.
6 sear spring screws.
6 side screws.
3 stock butts.
4 triggers.
6 tumblers.
6 tumbler screws.
6 trips.
6 trip springs.
6 nickel-plated scabbards, officers' swords.
4 steel scabbards, musicians' swords.

## CLASS X—VII.

197 saber belt attachments.
35 girth billets.
15 curb bits.
8 watering bits.
1,212 halter bolts.

24,173 brass bar buckles.
417 brass-plated buckles.
8,004 brass wire buckles.
7,769 iron bar buckles.
14,169 iron roller buckles.
3,000 brass canteen chains.
1,247 canteen corks and chains.
80 curb chains.
365 halter chains.
668 canteen covers.
1,000 brass D's for cartridge belts.
2,146 side line fasteners.
150 bayonet scabbard frogs, hook attachment.
60 bridle headstalls.
519 halter heads.
224 brass snap hooks for saber belts.
1,000 double hooks, brass wire.
100 double S hooks.
49 double spring hooks for lariats.
200 halter rope hooks.
206 sweat leathers.
2,050 curb strap loops.
1,756 ovals.
932 brass rings.
1,374 D rings.
1,342 halter rings.
1,852 iron rings.
1,000 swivel rings for halters.
50 curb chain safes.
10 shields.
4,436 snaps for lariats.
145 snaps for links.
622 snaps for side lines.
27 spring snaps, tinned.
716 halter squares.
1,308 brass foot staples.
2,834 brass staples for rings.
2,730 stirrups.
3 stirrups with guidon sockets.
5,247 canteen straps.
100 cincha straps.
2,452 clothing bag straps.
2,365 clothing bag straps, web.
728 coat straps.
1,311 curb straps.
6,193 halter straps.
1,489 halter hitching straps.
604 haversack straps.
388 hook straps.
2,614 stirrup straps.
24 yards webbing, 3½ inches wide.
84 yards linen webbing, 4 inches wide.
1,320 yards girth webbing, 4½ inches wide.
60 yards linen webbing, 7½ inches wide.
24 yards woolen webbing.

### CLASS X–VIII.

2,400 cartridge bags, ½-pound charge.
500 cartridge bags, 2-pounds charge.
2,250 cartridge bags, 6-pounder gun.
8,150 cartridge bags, 3-inch gun.
4,173 cartridge bags, 12-pounder gun.
400 cartridge bags, 12-pounder field howitzer.
6,745 cartridge bags, mountain howitzer.
800 cartridge bags, 24-pounder howitzer.
200 cartridge bags, 42-pounder.
1,950 cartridge bags, 4½-inch gun.
200 cartridge bags, 8-inch converted rifle.
500 cartridge bags, 8-inch Rodman gun.
898 cartridge bags, 10-inch gun.

### CLASS X–IX.

1 clevis bolt for garrison gin.
1 key-pin bolt for garrison gin.
46 target frames.
3 handles for Laidley targets.
2 sets irons for 2 sheave snatch blocks.
2 sets irons for 4 sheave blocks, lower.
2 sets irons for 4 sheave blocks, upper.
43 cross pieces.
36 upright pieces.
4 capstan pins.
18 brass sheaves.
2 capstan windlasses.

## PART SECOND.

### *Material, tools, &c.*

100 yards burlaps.
2,490 yards cotton cloth.
10½ pounds flax cord.
30 pounds rocket cord.
124 pounds sash cord.
135 pounds waste cotton.
44 yards cotton duck.
17 pounds lampwick.
37½ pounds marline.
18 yards cartridge-bag material.
248⅜ yards muslin.
20 pounds oakum.
900 feet rope.
2,906 pounds rope.
194 pounds assorted thread.
85¼ pounds linen thread.
54 pounds saddlers' thread.
525 pounds shoe thread.
315 pounds tow.
132 pounds twine.
7½ pounds woolen yarn.

2 hose bands and attachments.
6 iron bolts.
29 papers iron brads.
4 feet iron chain.
300 gas checks.
6 hose couplings.
800 pressure discs.
4 brass faucets.
36 pairs brass butt hinges.
12 copper hoops for powder barrel.
415 pounds bar iron.
1 pound copper nails.
1,280 pounds horseshoe nails.
2,625 pounds iron nails.
60 saddle nails, japanned.
120 saddle nails.
1 hose nozzle.
117 padlocks.
2 escutcheon pins.
152 gross escutcheon pins.
1 pound escutcheon pins.
10 sliding pulleys.
1 cooking range.
3 gross brass rivets.
32 pounds copper rivets.
235 pounds assorted rivets and burrs.
154 pounds brass rivets and burrs.
1,091 pounds copper rivets and burrs.
88 pounds iron rivets and burrs.
211 gross brass screws.
26 gross iron screws.
9,200 horseshoes.
400 pounds horseshoes.
100 pounds spikes.
191 pounds bar steel.
2,000 copper tacks.
104 papers copper tacks.
26 pounds copper tacks.
975,000 iron tacks.
692 papers iron tacks.
30¼ pounds iron tacks.
727 sides bridle leather.
24,739 pounds harness leather.
2 calf skins.
86 chamois skins.
3 sheep skins.
11,604 feet boards.
1,118 feet plank.
15,864 feet scantling.
720 feet timber.
100 pounds boracic acid.
42½ gallons alcohol.
153 pounds gum arabic.
2 gross elastic bands.
100 pounds nitrate baryta.
433 quarts leather blacking.

36 instruction books.
43 bath bricks.
14 ounces bristles.
40 pounds camphor.
19 pounds candles.
100 pounds pulverized charcoal.
48¼ quires crocus cloth.
1,387 quires emery cloth.
8,011 pounds coal.
50 pounds ammoniated sulphate of copper.
44 gallons Japan drier.
4 pounds patent drier.
75 pounds emery.
1,000 envelopes.
10 pounds flour.
1 barrel rye flour.
100 pounds glue.
820 pounds wheel grease.
3 pounds sulphate of iron.
5 boxes ingredients for blacking.
3 bottles black ink.
115 gallons lacquer.
54 papers lampblack.
15 pounds lampblack.
790 pounds red lead.
1,365 pounds white lead.
17 pounds extract of logwood.
876 pounds lubricant.
35 boxes cleaning material.
39¼ pounds polishing material.
142¾ pounds scouring material.
800 pounds refined niter.
5 pounds yellow ocher.
5½ gallons anti-corrosive lubricating oil.
103 quarts cosmoline oil.
5,464 pounds harness oil.
½ gallon headlight oil.
284 gallons kerosene oil.
13 gallons lard oil.
762¼ gallons linseed oil.
160½ gallons neat's-foot oil.
25 gallons neutral oil.
751½ gallons sperm oil.
1,433 pounds black paint.
100 pounds green paint.
720 pounds lead-color paint.
1,404 gallons metallic paint.
3,850 pounds metallic paint.
3,695 pounds olive paint.
1,000 pounds red paint.
10 quires metallic cartridge paper.
61 pounds drawing paper.
20 quires drawing paper.
60½ quires emery paper.
1,490 pounds laboratory paper.
1 ream letter paper.

2 reams note paper.
91½ quires sand paper.
144 pounds wrapping paper.
24 lead pencils.
2 gross metallic pens.
2 rulers.
2 pounds leather polish.
275 pounds chlorate of potash.
290 pounds putty.
62 bars castile soap.
2,583 pounds castile soap.
173 pounds common soap.
100½ pounds sponge.
633 pounds rotten stone.
200 pounds nitrate of strontia.
300 pounds flowers of sulphur.
200 shipping tags.
31 pounds tallow.
208 gallons coal tar.
558 papers tripoli.
723 gallons turpentine.
10 pounds burnt umber.
20 gallons varnish.
141¾ pounds beeswax.
458 pounds black wax.
1,010 pounds Japan wax.
2 pounds sealing wax.
22 gallons whisky.
105¾ pounds whiting.
15 leather aprons.
4 augers.
1,023 awls, assorted.
1 brad awl and handle.
35 peg awls and handles.
71 saddler's awls.
31 seat awls and handles.
1 stub awl and handle.
6 assorted axes.
9 felling axes.
5 bags for tacks, wax, &c.
3 tool bags for saddlers' and smiths' tools.
40 metallic powder barrels.
1,287 wooden powder barrels.
6 assorted bits.
1 extension bit.
26 bits for brace.
2 saw blades.
31 lead punching blocks.
1 dredging box.
6 boxes for forge and battery wagon stores.
7 boxes for cleaning material.
2 shoeing boxes.
6 boxes for sets reloading tools.
7 assorted braces.
250 corn brooms.
1 split broom.

3 assorted brushes.
1 button brush.
27 dusting brushes.
15 marking brushes.
30 brushes for oiling leather.
294 paint brushes.
57 sash brushes.
39 wire scratch brushes.
6 stencil brushes.
2 galvanized iron water buckets.
11 sheet-iron water buckets.
1 wooden water bucket.
3 buttresses.
1 calipers.
844 powder canisters.
4 oil cans.
46 tin cans.
9 pricking carriages.
6 chamois skin sword cases.
4 channelers.
48 powder chargers.
453 arm chests.
1 tool chest.
24 clamps.
6 carpenters' clamps.
17 chisels.
37 compasses.
53 creasers.
6 assorted dies.
6 crimping dies.
7 reloading dies.
11 resizing dies.
9 drifts.
1 drill.
22 oil droppers.
4 extractors and recappers.
6 hook extractors.
20 primer extractors.
195 files.
1 powder flask.
2 forks.
1 fuller.
7 copper funnels.
3 assorted gauges.
10 draw gauges.
10 gimlets.
3 gouges.
1 grindstone.
81 assorted hammers.
2 hand hammers.
3 riveting hammers.
8 saddlers' hammers.
1 shoeing hammer.
2 sledge hammers.
281 assorted awl handles.
37 patent awl handles.

3 axe handles.
7 chisel handles.
7 file handles.
14 pickax handles.
3 hardies.
11 hatchets.
1 hoe.
4 bill hooks.
10 extracter hooks.
8 reaping hooks.
8 saddlers' horses.
26 stitching horses.
100 feet rubber hose.
2 plane irons.
6 riveting irons.
4 rounding irons.
5 jackscrews.
80 powder kegs.
290 assorted knives.
2 drawing knives.
2 gauge knives.
4 half round knives.
5 head knives.
7 putty knives.
4 shoeing knives.
18 shoe knives.
13 splitting knives.
148 ladles.
16 chalk lines.
9 spirit levels.
6 extractor and recapper levers.
40 assorted mallets.
2 mauls.
4 tape measures.
4,925 needles.
8 collar needles.
43 harness needles.
62 nippers.
3 collar palms.
4 dusting pans.
6 carpenters' pencils.
12 pickaxes.
8 pincers.
111 primer extractor pins.
9 planes.
1 set stencil plates, letters, and figures.
16 pliers.
1 plow.
4 star gauge points.
2 pokers.
1 glue pot.
1 saddlers' tool pouch.
4 pritchells.
29 assorted punches.
15 hand punches.
3 nail punches.

6 primer punches.
19 reloading punches.
10 resizing punches.
26 saddler's punches.
43 spring punches.
123 rasps.
1 ratchet for cavalry forge.
1 star gauge ring.
7 wiping rods.
2 combination rules.
26 rules.
4 assorted saws.
1 cross-cut saw.
2 tenon saws.
1 counter scales.
22 scissors.
2 box scrapers.
8 shell scrapers.
4 primer extractor screws.
35 screw-drivers.
1 scriber.
7 scythes.
25 burr or rivet sets.
2 saw sets.
7 primer setters.
23 shears.
13 assorted shovels.
20 long-handled shovels.
1 sickle.
4 sieves.
22 slickers.
38 magazine slippers.
5 scythe snaths.
6 safety sockets.
29 spades.
2 spokeshaves.
3 squares.
1 straight starter.
1 button stick.
1 stock.
2 die stocks with dies and taps, complete.
19 oil stones.
33 sandstones.
4 scythe stones.
34 tin strainers.
6 taps.
18 thimbles.
19 ticklers.
5 tongs.
3 sets bench tools.
37 claw tools.
32 edge tools.
11 sets hand tools.
4 heading tools.
45 priming tools.
41 sets cartridge reloading tools.

221 sash tools.
4 wooden tubs.
1 forge vise.
7 hand vises.
2 wedges.
24 pricking wheels.
11 assorted wrenches.

# APPENDIX 4.

*Apportionment of ordnance, ordnance stores, &c., for the fiscal year ending June 30, 1881, under sections 1661 and 1667 Revised Statutes United States, and regulations established in conformity therewith.*

| States and Territories. | Number of Senators and Representatives. | Money-value. |
|---|---|---|
| Alabama | 10 | $4,797 85 |
| Arkansas | 6 | 2,878 71 |
| California | 6 | 2,878 71 |
| Colorado | 3 | 1,439 36 |
| Connecticut | 6 | 2,878 71 |
| Delaware | 3 | 1,439 36 |
| Florida | 4 | 1,919 14 |
| Georgia | 11 | 5,277 64 |
| Illinois | 21 | 10,075 49 |
| Indiana | 15 | 7,196 78 |
| Iowa | 11 | 5,277 64 |
| Kansas | 5 | 2,398 93 |
| Kentucky | 12 | 5,757 42 |
| Louisiana | 8 | 3,838 28 |
| Maine | 7 | 3,358 50 |
| Maryland | 8 | 3,838 28 |
| Massachusetts | 13 | 6,237 21 |
| Michigan | 11 | 5,277 64 |
| Minnesota | 5 | 2,398 93 |
| Mississippi | 8 | 3,838 28 |
| Missouri | 15 | 7,196 78 |
| Nebraska | 3 | 1,439 36 |
| Nevada | 3 | 1,439 36 |
| New Hampshire | 5 | 2,398 93 |
| New Jersey | 9 | 4,318 06 |
| New York | 35 | 16,792 48 |
| North Carolina | 10 | 4,797 85 |
| Ohio | 22 | 10,555 27 |
| Oregon | 3 | 1,439 36 |
| Pennsylvania | 29 | 13,913 76 |
| Rhode Island | 4 | 1,919 14 |
| South Carolina | 7 | 3,358 50 |
| Tennessee | 12 | 5,757 42 |
| Texas | 8 | 3,838 28 |
| Vermont | 5 | 2,398 93 |
| Virginia | 11 | 5,277 64 |
| West Virginia | 5 | 2,398 93 |
| Wisconsin | 10 | 4,797 85 |
| Arizona Territory* | 3 | 1,439 36 |
| Dakota Territory* | 3 | 1,439 36 |
| Idaho Territory* | 3 | 1,439 36 |
| New Mexico Territory* | 3 | 1,439 36 |
| Montana Territory* | 3 | 1,439 36 |
| Utah Territory* | 3 | 1,439 36 |
| Washington Territory* | 3 | 1,439 36 |
| Wyoming Territory* | 3 | 1,439 36 |
| District of Columbia* | 3 | 1,439 36 |
| Total | 396 | 189,995 00 |
| Freights, &c | | 10,005 00 |
| | | 200,000 00 |

* Apportionment according to the first paragraph of the President's regulation of April 30, 1855.

## APPENDIX 5.

*Statement of ordnance, ordnance stores, &c., distributed to the militia from July* 1, 1880, *to June* 30, 1881, *under sections* 1661 *and* 1667 *Revised Statutes United States.*

### CLASS I.

2 10-pounder rifled guns, caliber 2.9.
1 12-pounder field howitzer.
4 6-pounder bronze guns.
1 3-inch wrought-iron rifled gun, model 1861.
2 Gatling guns, 10 barrels, long, caliber .45.
4 Gatling guns, caliber .50, model 1880.

### CLASS II.

2 carriages for 10-pounder guns.
5 carriages and limbers for 6-pounder guns.
1 carriage and limber for 3-inch gun.
2 carriages and limbers for Gatling guns, caliber .45.
4 carriages and limbers for Gatling guns, caliber .50.
1 caisson and limber for 3-inch gun.
1 limber for 3-inch gun.

### CLASS III.

416 feed cases.
2 fuse wrenches.
2 fuse blocks.
2 fuse cutters.
2 fuse gouges.
19 gunners' haversacks.
5 gunners' gimlets.
4 gunners' pincers.
17 handspikes, trail.
20 lanyards for friction primers.
15 priming wires.
9 prolonges.
16 tube pouches.
36 thumbstalls.
6 tow hooks.
11 tompions.
11 paulins, 12 by 15 feet.
12 vent covers.
2 pendulum hausses.
4 pendulum hausse-pouches.
1 pendulum hausse-seat.
34 sets of artillery harness, 2 horses, wheel.
28 sets of artillery harness, 2 horses, lead.
5 sponge buckets, iron.

16 sponges and rammers, 12-pounder gun.
2 sponges and rammers, 12-pounder howitzer.
26 sponges and rammers, 10-pounder gun.
14 sponges and rammers, 6-pounder gun.
14 sponges and rammers, 3-inch gun.
6 sponge covers, 12-pounder gun.
4 sponge covers, 10-pounder gun.
14 sponge covers, 6-pounder gun.
12 sponge covers, 3-inch gun.
6 worms and staves, field gun.
3 worms and staves, 3-inch gun.
2 staves, 3-inch gun.
1 Gatling gun cover.

### CLASS V.

12 12-pounder shells, strapped.
12 12-pounder canister, filled.
12 12-pounder grape, stands.
50 6-pounder shot, strapped.
50 6-pounder spherical case shot, strapped.
16 3-inch Absterdam case shot.

### CLASS VI.

#### MUZZLE-LOADING.

160 Springfield rifle muskets, caliber .58.

#### BREECH-LOADING.

5,285 Springfield rifles, caliber .45.
230 Springfield rifles, cadet, caliber .45.
81 Springfield carbines, caliber .45.
117 Colt's revolvers, caliber .45.
301 Schofield's Smith & Wesson revolvers, caliber .45.
40 officers' swords.
125 non-commissioned officers' swords.
100 light cavalry sabers.
57 artillery sabers.
10 bayonets for caliber .50.
30 bayonets for caliber .45.
97 Springfield rifles, caliber .50.

### CLASS VII.

1,000 knapsacks and straps.
6,021 waist belts and plates.
6,491 cartridge boxes.
5,931 steel bayonet scabbards.
120 non-commissioned officers' waist belts and plates.
20 non-commissioned officers' sword frogs.
371 saber belts and plates.
230 carbine slings.
230 carbine sling swivels.
60 carbine cartridge pouches.

3,300 gun slings.
300 canteens and straps.
180 waist belts.
1,900 waist belt plates.
23 pistol holsters.
22 curb bridles.
2 artillery bridles.
22 cavalry saddles.
181 saddle blankets.
2 artillery drivers' saddles.
34 whips.

### Class VIII.

50 blank cartridges for 12-pounder howitzer.
540 blank cartridges for 10-pounder gun.
895 blank cartridges for 3-inch gun.
25,000 musket blank cartridges, caliber .58.
1,000 musket, elongated ball cartridges, caliber .58.
34,000 rifle blank cartridge, caliber .50.
24,000 rifle blank cartridges, caliber .45.
597,000 rifle ball cartridges, caliber .50.
140,000 rifle ball cartridges, caliber .45.
2,000 carbine blank cartridges.
600 carbine ball cartridges.
1,350 revolver ball cartridges.
6,000 round balls.
2,000 percussion caps.
3,000 pounds mortar powder.
25 pounds musket powder.
15,680 friction primers.
16 time fuses, paper.
15,000 cartridge primers.
600 reloading cartridge shells.
1,000 carbine cartridges, metallic, caliber .50.

### Class X.

16 time fuse plugs.
1 pole.
25 pole pads.
29 pairs pole straps.
1 ammunition chest for 3-inch gun.

*Spare parts for Springfield rifle, caliber .50.*

151 stocks.
500 ejector spring spindles.
25 hinge pins.
157 rear sights.
50 rear sight leaves.
25 rear sight leaf springs.
51 locks.
100 tumblers.
50 tumbler screws.
50 bridles.

50 bridle screws.
50 sears.
50 sear screws.
27 upper bands.
25 upper band screws.
25 lower bands.
10 breech blocks.
50 bayonet clasps.
100 bayonet clasp screws.
1 guard bow swivel.
2 ramrods.
6 firing pins.

*Spare parts for Springfield rifle, caliber .45.*

20 ejector studs.
200 ejector spring spindles.
202 rear sights.
20 breech blocks.
140 breech block caps.
20 breech block cap screws.
40 cam latches.
25 front sights.
12 hammers.
40 thumb-pieces.
2 sears.
200 ramrod stops.
20 firing pins.
6 side screws.
1 spare wheel.

MISCELLANEOUS.

1 set hand reloading tools.
1 pouring ladle, 2½ inches.
1 melting ladle, 7 inches.
1 tin strainer.
1 bullet mold (4 balls).
1 adjustable charger.
25 pounds bullet lubricant.
5,000 pasters, white.
1,000 pasters, black.
100 paper targets.
5 arm chests.
1 armorer's tool chest.
2 axes.
1 anvil.
1 brace and screw-driver.
6 cold chisels.
7 files, assorted.
6 file handles.
2 gouges.
2 hammers.
2 pickaxes.
12 padlocks.
1 pair vise clamps.

1 pair plyers.
4 punches.
2 pairs tongs.
1 hand screw-driver.
1 drill stock.
1 hand vise.
1 bench vise.
2 wrenches, various.
2 wiping rods.
2 long-handle shovels.

## APPENDIX 6.

***Statement of ordnance, ordnance stores, &c., distributed to colleges and universities, from July 1, 1880, to June 30, 1881, under section 1225 Revised Statutes United States, as amended by act approved July 5, 1876.***

### CLASS I.

2 6-pounder bronze guns.
4 3-inch wrought-iron rifled guns, model 1861.

### CLASS II.

2 carriages and limbers for 6-pounder guns.
4 carriages and limbers for 3-inch guns.

### CLASS III.

6 gunners' haversacks.
6 handspikes, trail.
12 lanyards.
6 priming wires.
6 tube pouches.
12 thumb-stalls.
6 tompions.
8 paulins, 12 by 15 feet.
6 vent covers.
1 pendulum hausse.
1 pendulum hausse pouch.
1 pendulum hausse seat.
4 sponges and rammers for 6-pounder gun.
8 sponges and rammers for 3-inch rifled gun.
4 sponge covers for 6-pounder gun.
8 sponge covers for 3-inch rifled gun.

### CLASS VI.

#### BREECH-LOADING.

255 Springfield rifles, cadet, caliber .50.
50 artillery sabers.

### CLASS VII.

396 waist belts.
565 waist belt plates.
225 cartridge boxes.
50 saber belts and plates.
255 steel bayonet scabbards.
139 leather bayonet scabbards.

### CLASS VIII.

200 blank cartridges for 12-pounder gun.
900 blank cartridges for 6-pounder gun.
1,200 blank cartridges for 3-inch gun.
6,500 carbine blank cartridges, caliber .50.
11,000 carbine blank cartridges, caliber .45.
7,500 carbine ball cartridges, caliber .50.
12,000 carbine ball cartridges, caliber .45.
2,000 rifle blank cartridges.
2,000 rifle ball cartridges.
6,500 friction primers.

## APPENDIX 7.

***Statement of ordnance stores issued to the executive departments during the year ended June* 30, 1881, *under the provisions of the act of March* 3, 1879.**

TO THE TREASURY DEPARTMENT.

| | |
|---|---|
| 3 | Gatling guns, long barrels. |
| 1 | Gatling gun, short barrel. |
| 1 | tripod for Gatling gun. |
| 300 | feed cases for Gatling guns. |
| 1,500 | Ketcham's hand grenades. |
| 125 | Springfield carbines. |
| 100 | Colt's revolvers. |
| 6 | carbine slings and swivels. |
| 6 | cartridge boxes. |
| 106 | waist belts and plates. |
| 100 | pistol cartridge pouches. |
| 100 | pistol holsters. |
| 13,300 | carbine ball cartridges. |
| 1,000 | rifle ball cartridges. |
| 1,200 | revolver ball cartridges. |
| 1 | box of cleaning materials. |

## APPENDIX 8.

### REPORT OF ACTION TAKEN UNDER THE ACT OF MARCH 3, 1881, DURING FISCAL YEAR ENDING JUNE 30, 1881.

#### SOLD.

March 8, 1881.—To I. D. Goodwin:

| | | |
|---|---|---|
| 22,200 pounds cannon powder. | from broken up ammunition. | |
| 1,100 pounds mixed powder. | | |
| 200 pounds mortar powder. | | |
| 23,500 pounds at 8 cents per pound | | $1,880 00 |
| June 14, 1881.—To I. D. Goodwin: | | |
| 6,000 pounds musket powder from broken up ammunition at 8 cents per pound | | 480 00 |
| Total proceeds | | $2,360 00 |

Other sales were in progress but were not completed during the year.

On June 24, 1881, a contract was made with E. I. Du Pont de Nemours & Co. for 50,000 pounds hexagonal powder, at $25\frac{4}{10}$ cents per pound.

# APPENDIX 9.

REPORT OF THE PRINCIPAL OPERATIONS AT THE ROCK ISLAND ARSENAL, ILL., DURING THE FISCAL YEAR ENDED JUNE 30, 1881, MAJOR D. W. FLAGLER, ORDNANCE DEPARTMENT, COMMANDING.

[Eight plates.]

## SHOP G.

(An iron working and finishing shop for the arsenal.)

### MASONRY.

All the stone for the steps and platforms, and copings for area walls, and flagging of areas has been purchased; and all the masonry for the steps, areas, and area walls has been built. A portion of the flagging for walks around the building has been purchased, cut, and laid.

The grading in front of the building and in the court has been completed, and the court macadamized, and all the sewers (about 650 feet), and all the drain sewers (480 feet), and stench traps from areas and down spouts have been put in.

### IRON WORK.

As stated in my last annual report, the bar iron for the roof rods was manufactured from scrap in the arsenal rolling-mill. The beams and purlins required for the roof frame were purchased during the year, and the roof frame manufactured complete in the arsenal shops during the winter, and put on the building during the spring.

The tests of the bar iron made in the arsenal mill gave better results than the purchased bar used in the other roofs, and in some respects this roof frame is better made and is a better frame than those on the other shops.

Attention is respectfully invited to a new method employed in making the eyes of the truss rods of the roof frame. (See Plate 1, appended hereto.) With the first heat, the metal is upset and the bar enlarged at A (Fig. 1), with a special machine designed and made therefor in the shops; the welding scarf at S is made, and the end of the bar is brought around, and the eye formed as shown in Fig. 2. The enlargement of the bar at A is very important, as will be shown further on.

The button B, which is a piece of round bar large enough to fill the hole H (Fig. 2), and as long as the diameter of the rod R, is then heated to a welding heat nearly, inserted endwise in the hole H, the whole eye is then brought to a welding heat, the weld at A carefully made, and the eye E (Fig. 3) is formed under a steam hammer with the same heat, using dies in the ordinary way. After exact measurements for length (the maximum variation being $\frac{1}{64}$ of an inch), the pin hole *h* is drilled in the proper place, in each end of the bar.

A consideration of this process will show that the fiber of the bar is

disposed exactly as it should be in forming the eye, and the tests show, and I believe this eye-bar is better than those made in any other way with which I am acquainted.

The objections to forming a bar in this way have heretofore been;

First. If the end of a bar is brought around and welded at A in the ordinary way, the hammering to form the bar pins out and reduces the size of the bar just to the right (in the drawing) of the end of the weld; and also, the heating and hammering *may* change the character of the iron and further weaken the bar at this point. It is a fact that eye-bars made in the ordinary way, usually break, if at all, at this point. The enlargement of the bar at this point as described above, overcomes this objection.

Second. In making eye-bars for engineering purposes, bridges, roof frames, &c., when the smith has finished the eye to the form in Fig. 2, he cannot give the *exact* length of bar required between the eyes at the two ends of the bar, and therefore, when the bar is finished to the form in Fig. 3, an excess of metal must be left in the eye to allow for a slight variation in locating and drilling the hole *h*, and still leave the bar as strong or stronger in the eye than anywhere else. This objection is overcome and the excess of, or additional metal required is obtained by inserting the button B as described.

The pin hole *h* (Fig. 3) when drilled is drilled in the metal of the button B, so that it cuts none of the valuable fiber that runs *around* the hole, and the fiber lining the hole lies parallel to the axis of the hole or pin.

The separate heating of the button B before inserting it in the hole H, and just before putting the eye in the fire for the second heat, is very important. Without it the mass of iron would not be sufficiently heated at the center to insure a perfect weld.

A large number of eye-bars of both good and bad iron, and both well and badly made, were tested. In no case did a bar break in the eye or in the weld. As this process is a cheap one, and suited to the machinery of most shops, and the shape and method of construction of eye-bars an important matter in engineering constructions, the process is described and reported here.

### OTHER WORK DONE ON SHOP G.

In the roofs of the other shops small skylights have been inserted at various places for improving the light of the third story. These are found to give insufficient and bad light for shop purposes. The third stories of these shops can be used most advantageously for harness and equipment shops, but this use requires a strong light.

I have left the scattered skylights out of shop G, and put a continuous skylight 5 feet wide around the whole building on one side of the peak. It furnishes an excellent light, improves very much the general appearance of the interior, and gives such ventilation as to make the temperature about the same as in the other stories in hot weather.

The roof has been put on and completed. The fire-proof arches for all the floors have been put in, the floors laid, the doors and windows put in, and the painting, plastering, building the iron stairs, and putting in the basement floor are now in progress, and will be completed and the building entirely completed about October 30.

Attention is invited here to the highly beneficial results arising from the decision of the Second Comptroller of the Treasury, that the appropriations for buildings at this arsenal were exempted from the action

of the act of July 12, 1870, requiring unexpended balances of appropriations to be turned into the Treasury at the end of the fiscal year.

This decision was made August 25, 1880. Without it it would have been necessary to employ between one and two hundred extra workmen during the spring months, and force the building to completion before June 30, involving useless expense and the danger of imperfect work. As it is, the work is being done very economically and perfectly with the regular force of workmen, in bad weather and at times when outside work is slack.

### SHOP I.

(A wood-working and leather-working shop for the arsenal.)

The work done on this shop during the fiscal year is as follows:

#### IRON WORK.

The beams for one-half of the second floor have been purchased, drilled, and fitted, and the columns, caps, bases, and other iron work for the same have been manufactured in the arsenal shops and this iron work put up.

#### STONE WORK.

The stone for the second story has been purchased, cut, and this story has been built and completed. Nearly all the stone for the third story has been purchased and cut.

#### WOOD WORK.

All the clear lumber required for the sash, window and door frames, and doors has been purchased and stacked for seasoning, and a portion of this wood work was made during the winter months to keep workmen employed.

### SHOP H.

(An iron-finishing shop for the armory.)

The work done on this building during the fiscal years is as follows:

#### IRON WORK.

All the iron beams for the first floor have been purchased, drilled, and fitted in the arsenal shops and put in position in the building.

#### STONE WORK.

Part of the stone for the first story has been purchased, all of it cut, and the building of this story was in progress and about half completed at the close of the fiscal year. About one-fourth of the stone required for the other two stories was purchased and cut during the year.

### AN ELEVATED IRON WATER-TANK FOR FIRE PROTECTION, AND FOR SUPPLYING THE POST BUILDINGS WITH WATER, AND A GENERAL DESCRIPTION OF ARSENAL WATER-WORKS.

The elevated tank, the masonry tower for supporting it, and the building for inclosing it, have been built and completed during the year.

The tank and masonry, calculations for strength and capacity, and arrangement of pipes, gates, valves, &c., are shown in Plate 2.

The exterior of the tower and building is shown in Plate 4.

Plate 3 gives the details of the timber floor on the tower for supporting the tank, and the details of the joint between the iron walls and floor of the tank. The tank was made entirely in the arsenal shops, and is all ordinary boiler work except the joint just mentioned.

The location of the new elevated tank is shown at E (Plate 5). Prior to the building of this tank the constructions for the water supply of the arsenal had progressed as far as the following (see map on Plate 5): A stone reservoir A, with a capacity (if filled) of 850,000 gallons; an 8-inch main (*a a a*) from the reservoir extending entirely around the ten shops and down to the main pump B, and filtering beds in the water-power pool at C. The pump B forces the water directly through the 8-inch main (having no separate pump-pipe), so that the reservoir serves as a stand-pipe when the pump is working. The pump B is driven by the water-power, and the cost of pumping is practically nothing.

As the water-power machinery may sometimes be stopped for repairs or for other causes, and the water at times be drawn out of the pool for repairs of dams, gates, &c., there is another small pump (steam) on the other side of the island at D, and an imperfect pipe (of various sizes, and too small) from it to the reservoir A, and a small pipe from the reservoir to the officers' quarters and barracks.

There are excellent fire plugs (*b b b b*) on the 8-inch main at each of the shops and at some other points for use in connection with the steam fire engine. The reservoir is divided into two compartments by a division wall 15 feet high, so that by lowering the water to the top of this wall either side can be used while the other is emptied for repairs. It is supplied with separate pipes and gates for receiving water from the pumps, for filling the mains, and for draining the two compartments separately.

The defects of the system which are to be remedied by the new elevated tank and new water mains and other appliances connected with it are as follows: Owing to the extreme cold of this climate the water pipes are buried 5 feet below the ground surface. The six water gates in these pipes about the reservoir are surrounded with masonry walls and covered; but this is not enough to protect them from frost, and in winter these wells must be filled with hay manure or some other protection. Getting at them is difficult, and they are generally rusted, and it takes sometimes a day to open or close one. It should be done in a few minutes. To overcome this all these pipes are now taken through the room in the tower underneath the new tank. This room will be warmed in winter, and all the gates and valves will be placed there and kept in perfect condition, so that they can be operated quickly and with certainty.

The reservoir furnished no sufficient head for fire purposes, though the system of water-mains (*a a a a*) south of the reservoir—that is, the system about the shops and adjoining buildings—has fire plugs, and ample capacity for fire purposes. The system north of the reservoir (*c c c c*)—that is, the system that should supply the quarters, barracks, hospital, and stables—has neither head capacity nor fire plugs for fire purposes, and is imperfect and incomplete.

The reservoir head is sufficient for the ordinary service of the system south of the reservoir; and for economic reasons this head only will be used in these mains, ordinarily, but in case of fire, the elevated tank head can be turned on to these mains at a moments warning. This

elevated tank head is sufficient to operate fire hose on all the floors of the shops. It is taken into account that an exterior fire is nearly impossible on these fire-proof buildings. The tank head is not sufficient for throwing a stream through fire hose from the ground outside onto the roofs of the shops. If such a fire should ever occur, the service of the fire engine at the fire plugs is to be used. For very economic reasons, the plans embrace also a small tank in each shop under the roof, to be filled only when the shop is in use, and warmed, and then by a small pump in the shop attached to the shafting. The small head of the reservoir will supply constantly the basement and first floors where nearly all the water is used, and will be the only head pumped against by the great pumps (B and D), and the only regular head and pressure on all the great mains. If the upper floors of any particular shop are in use, the small tank in the shop will furnish a constant head at all times to the fire hose on those floors, and also any water that may be wanted on those floors for ordinary use. Shops not in use are not subject to fire, require no water, and being unwarmed, no water can be allowed in the pipes on account of frost.

A complete, new, and separate system of 4-inch mains, and supplied with fire plugs, is being laid north of the reservoir for the service of all the quarters, barracks, hospital, and stables. The head of the new elevated tank will be always on this whole system, not only for fire protection to these buildings in which fires are more likely to occur, but for regular use on all the upper floors. This system is marked *c c c* on the map (Plate 5), and its fire plugs are marked *f f f f f*. There are about 5,000 feet of 4-inch pipe in this new system and in the new pump pipe from pump D to the reservoir and tank. This new pipe was made economically in the arsenal foundry last winter when other work was slack.

The stone reservoir was built on imperfect foundations, of not durable stone, and the walls are liable to fail at any time. It was specially important to have the new elevated tank for the supply of the arsenal when the reservoir should fail, or the arsenal would be left without any water supply whatever. It is proposed to continue to use this reservoir, as has been described, as long as it lasts. When it fails, it should be replaced by a larger cheap open reservoir, to perform the same service and to be located on good rock foundation just east of the new elevated tank. The pipes, gates, &c. (to be described further on), are arranged for easy connection with the reservoir in the new position. It has been stated that the elevated tank will supply regularly the quarters, barracks, and hospital. These buildings require the purest water obtainable. On this account, as will be shown further on, the elevated tank will be supplied generally with water taken from the reservior only; this having been not only filtered, but also allowed to settle several days. The reservoir is therefore important, not only for the uses which have been described, but also as a settling reservoir. The location of the reservoir and new tank, and of all the pumps, water mains, and fire plugs, both old and new, and their relations to buildings are shown on Plate 5.

The arrangement of all the pipes, gates, &c., in the elevated-tank tower, for carrying out all the plans hereinbefore described, are shown on Plate 2, and are as follows:

The objects to be effected are to pump water into the reservoir A, or the elevated tank E, at will, with either of the pumps B and D; to turn the head of water in the reservoir or tank into either of the two systems of mains at will, and to fill the tank from the reservoir.

(Plate 2, Fig. 2.) *a* is the 8-inch main coming in from the pump B, and it is through this same main that water from both reservoir and tank pass back into the mains *a a a a* for the shops, &c. R R[1] are continuations of this main, leading into the two compartments of the reservoir, both supplied with 8-inch gates at *r* $r^1$. E is a vertical 6-inch pipe supplied with a gate leading up into the elevated tank. *p* is the 4-inch pipe coming in from the pump D, and is supplied with a gate at P. When the gate in pipe E is closed, and gates *r* and $r^1$ (either or both) are open, either pump can fill the reservoir. When the gate E is open and *r* and $r^1$ are closed, either pump can fill the elevated tank. The first arrangement of the gates, turns the head of the reservoir, and the second arrangement the head of the tank on to the *a a a* system of mains, both when the pumps, or either of them, are working, and when they are not.

C is a vertical 4-inch pipe supplied with a gate, coming down from the elevated tank, and supplies the *c c c* system of mains at all times, whether the pumps are working or not.

S is a connecting pipe between the pipes *c* and *p*, and is supplied with a gate, kept habitually closed. By opening it and closing P the reservoir head can be turned on to the *c c c* system of mains, temporarily, while washing out, or repairing the elevated tank.

T is the small steam pump to be used habitually for filling the elevated tank with settled water taken from the reservoir.

The 4-inch pipe W (with valves *w w*) supplies the pump, and the 4-inch pipe *e* returns the water to the vertical pipe E above its gate. O is a boiler to supply this pump with steam.

The pump T, has a capacity of 150 gallons per minute, two-horse power, and should be run about five hours per week for the regular supply and consumption of the *c c c* system of mains.

In case of a protracted fire, involving the possibility of exhausting the elevated tank, either pump B or D would be used to keep it full. H is a large coal heater to be used in winter to keep water in pipes, gates, and tanks from freezing. Fig. 1, Plate 2, shows that the floor on which the pipes are laid is 5 feet below the surface of the ground outside, so that all pipes laid below frost outside come in on the floor without curves. The building is also banked outside.

F (Fig. 2) is a chimney flue for the boiler O, and heater H. M is a projection on the tower to furnish a ladder-way into the tank.

D is a 4-inch drain pipe (supplied with a gate) for emptying the tank.

The tank has an interior vessel (not shown) holding two barrels, and so arranged that it will not be emptied when the tank is. This is to retain a convenient supply of water for washing out the tank.

As stated, the tower and tank are completed. The *c c c* system of mains are now being laid, when it can be done most conveniently, and will be finished and connected with the reservoir and tank before frost this fall.

## IMPROVEMENT OF THE WATER-POWER POOL.

In the appropriation act for sundry civil purposes, approved June 16, 1880, Congress made an appropriation of $50,000 for the improvement of the water-power pool. As this appropriation was based upon plans and estimates submitted to you in my report of February 4, 1876, it was understood that the work done with the appropriation should be confined substantially to the objects set forth in that report; that is, to removing

deposits and rock which obstruct the flow of water into the pool at low water and in winter, and to a short extension of the wing-dam.

As explained to you in my letter of July 21, 1880, the unprecedented high water in the river last fall rendered coffering for the removal of rock and deposits impracticable without great waste of money, and this part of the work could not, therefore, be done.

A long study of the water-power has convinced me that deposits could be very economically washed out of the pool, if means could be provided for producing a considerable current through the pool at low water. This could only be done by providing a large outlet from the pool. Of course, the gates at the water-ways through the dams would provide such an outlet, but these gates as constructed could not be opened when the pressure of the water head was on them, and their great distance from the deposits would make them ineffectual compared with an outlet near the deposits.* The old dike between Rock Island and Benham's Island afforded an excellent place for such an outlet.

In my annual report for the fiscal year ending June 30, 1880, is given a full description and drawing of a cast-iron gate devised by me to replace some of the old wooden ones that were failing or had warped so much that they could not be operated. The use of three of these gates made at that time showed, as predicted, that they could be readily opened with the pressure against them of the head of water in the pool.

After much study I was convinced that water-ways in the Benham's Island dike provided with these iron gates afforded such probability of enabling me to wash the deposits from the pool cheaper than they could be removed in any other way that I deemed it a proper expenditure of a portion of the appropriation to make the attempt. I proposed to build a short piece of cheap dam sufficient for six water-ways, each 9 feet wide, to be provided with the iron gates. When this plan was explained to members of the Moline Water-Power Company they not only approved of it, but were so sanguine of its success that they strongly urged a much longer dam and larger number of water-ways. They believed it would not only effect the immediate object intended, but would afford a certain means of keeping the pool free from deposits hereafter. They feared, however, that the six water-ways would not give a large enough outlet.† At their earnest solicitation the number of water-ways was finally increased to fifteen. I was the more willing to do this, because the dike had been much injured by the freshet in June, 1880, and the posts where the new dam and water-ways were placed required renewing. This dike is properly a part of the pool, and the work on it is part of the improvement of the pool. It should be stated here that putting in the nine additional water-ways extended the work into the cold weather of December; and ice, rises of the river, loss of coffer-dams, and other causes made the cost of each of these water-ways about double that of each of the first six of the original plan.

The two pieces of dam put in, and the water-ways are shown on Plate

*These gates were intended to be opened only when a pen-stock or fore-bay should be built behind them. The pen-stock could then be filled through a wicket in the gate, the water raised to the same height on both sides of the gate, and, all pressure being removed, the gate could be operated.

†My plan was by means of a movable plank fence or dam (to be used at extreme low water in connection with the construction of the coffer-dam across the pool), to hold a small stream of water up against the side of the bar, and so gradually cut and wash it away. The six water-ways were ample for the escape of this small stream. All of this plan was not described to the water-power company, and is not fully described here, though it is still proposed to use or attempt it, if the opportunity offer, and it should be necessary.

6. Fig. 1, is an elevation, Fig. 2 a plan, and Fig. 3 a larger elevation and cross-section, showing also one iron gate and appliances for hoisting it. A (Fig. 3) is a special hydraulic jack designed and made here for hoisting the gate. (An enlarged drawing of this jack is given on Plate 7.) B is a movable timber on which the jack stands. C is an eye-bolt in the wall to which the rear end of the timber is secured. One of these eye-bolts is placed over each water-way, and the timber, hydraulic jack, and hoisting rod D can be moved from gate to gate and used for hoisting them all, thus avoiding the expense of special hoisting arrangements for each gate. The dams are faced front and rear with good rough, durable Anamosa and Grafton stone, and the water-ways and arches are built of the same. The interior of the walls are built of rough stone found mixed with dirt in the old dike, and stone taken out of the river, and quarried along the island shore. Portland cement was used throughout. The dams were cheap, but are, I believe, more durable than any that have been built on the water-power. They are massive, being 15 feet thick at the bottom, and 10½ feet thick at the top. As shown, no attention was paid to the levels of the water-way sills. Each was placed as low as it was economical to excavate in getting foundations, and the varying heights of the water-ways were filled by making one of the plates which form the iron gates vary in width to suit.

Plate 7 shows the special hydraulic jack designed for hoisting the gates. The drawing shows the jack sufficiently without explanation. A is a special automatic clamp for griping and holding the hoisting rod while being lifted, but will slide down on the rod when the jack piston is lowered. B is the alternate automatic clamp that holds the rod while the other is being lowered, but allows the rod to pass up without resistance.

It was stated that the water-ways in the other dams would be less effectual than these new ones, because of their great distance from the bar to be washed out. It was determined, however, to take advantage of whatever effect these openings would give, and I have during the year made 45 new iron gates for these water-ways also. The gates made expressly for this washing out have been charged to the appropriation for the improvement of the pool. Those made to replace damaged gates have been charged to the appropriation for general care and preservation, as repairs of the water-power.

## EXTENSION OF WING-DAM.

Plate 8. The extension of the wing-dam contemplated in the plans was made during the year. It is comprised between the points marked BB on the map or Plate 8, and is 1,050 feet long. The upper end is in water 12 feet deep (below extreme low water). The whole dam is built to a height of 3 feet above extreme low water. Cross sections of the dam are shown at three places. The rock for this dam was excavated from the old "dump" of rock taken out of the water-power canal nine years ago. It was hauled on the ice about two miles to the site of the dam during the extreme cold of mid-winter, and the dam was constructed by simply cutting a channel in the ice over the site of the dam and dumping the rock into it. This extension contains 9,760 cubic yards of rock.

A contract was made during the year for excavating so much of the channel through Moline chain, proposed in the plans, as the appropriation would permit, but, as stated, the high water prevented this work, and it will be done during low-water stage this fall.

The Moline Water-Power Company has sent me a paper prote ing

against the excavation of this channel in accordance with the plans, and requesting that the appropriation be all expended in carrying out my plans for washing out the pool in a long extension of the wing dam, and in deepening the tail race for the benefit of their company exclusively. As this was not in accordance with the plans for which the appropriation was made, a compliance with their request was impracticable, even had it been desirable.

### GENERAL CARE AND PRESERVATION—IMPROVEMENT OF GROUNDS, &C.

The principal items of work done during the year, under this head, are: The manufacture of the 5,000 feet of 4-inch water pipe, heretofore mentioned; the construction and repairs and preservation of avenues, streets, and walks; care and preservation and repainting of buildings and bridges; care and preservation of water-power dams, and making new iron gates therefor.

Attention is respectfully invited to the fact that in consequence of the great extent of avenues, roads, bridges, and grounds to be taken care of; the number and magnitude of the buildings to be taken care of and kept painted; the extent of dams, &c., pertaining to the water-power, and the imperative necessity of carrying on the improvement of the grounds as the work of construction goes on, the appropriations made for this work during the past few years have been much too small. It is very desirable that the whole amount asked for under this head in the annual estimate for this year should be appropriated.

### ROCK ISLAND BRIDGE AND SHEER BOOMS FOR THE PROTECTION OF THE BRIDGE PIERS.

Appended hereto is a report for the year of public and railroad traffic on the bridge, and of the traffic on the river that has passed through the draw. (Appendix A.)

The opinions of river men are almost unanimous that the boom in the middle of the river is more an obstruction than an advantage to the passage of rafts, and therefore this boom was not replaced in position this spring, 1881.

Considerable difficulty is sometimes encountered by vessels in making the sharp turn around the island shore, and in getting safely into the draw passage in its position close to the shore, so far from the river channel. Some vessels have been injured by striking the rocks along the shore. I have, therefore, constructed during the year a considerable extension to the sheer boom to be placed along this shore, and am now waiting for low water to make the anchorages (economically) for this boom, and to place it in position.

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## APPENDIX A.

*Abstract of record kept at the Rock Island Bridge during the year.*

PASSING NORTH.

| | |
|---|---|
| Engines with trains | 5,321 |
| Engines without trains | 470 |
| Total engines | 5,791 |
| Passenger cars | 7,009 |
| Freight cars | 105,842 |
| Foot passengers | 225,649 |
| Teams | 174,653 |
| Steamboats | 1,270 |
| Barges | 239 |

PASSING SOUTH.

| | |
|---|---|
| Engines with trains | 5,437 |
| Engines without trains | 319 |
| Total engines | 5,756 |
| Passenger cars | 6,961 |
| Freight cars | 104,195 |
| Foot passengers | 235,213 |
| Teams | 117,537 |
| Steamboats | 1,285 |
| Barges | 243 |
| Rafts | 826 |

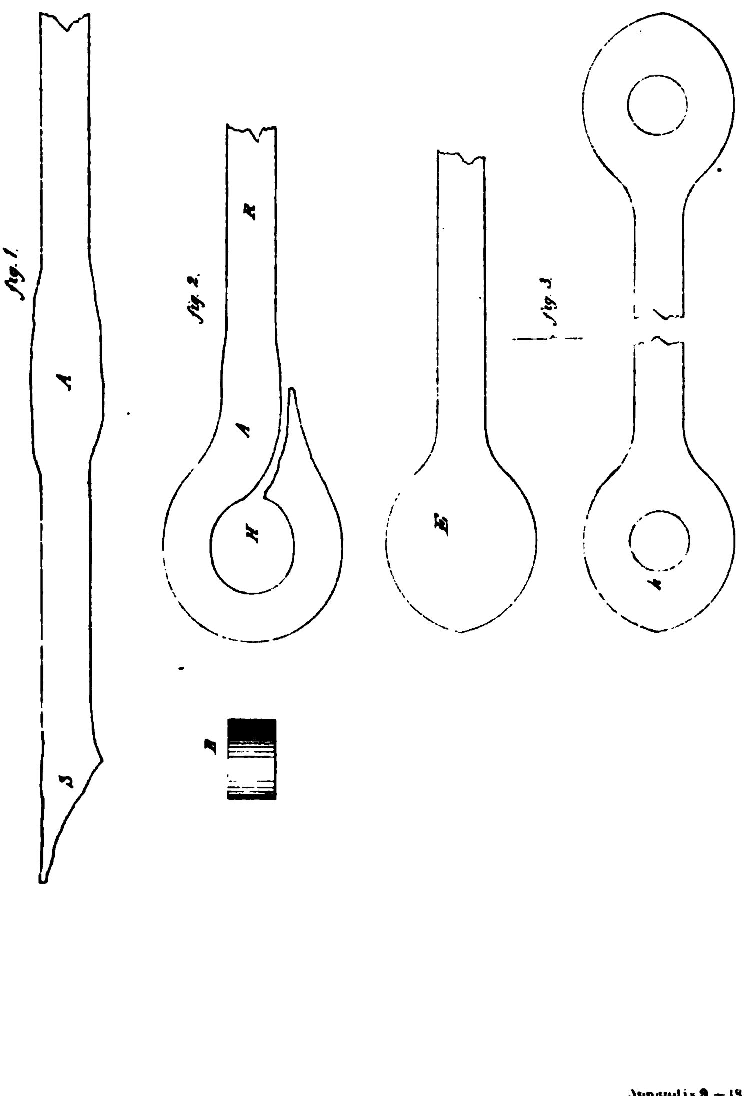
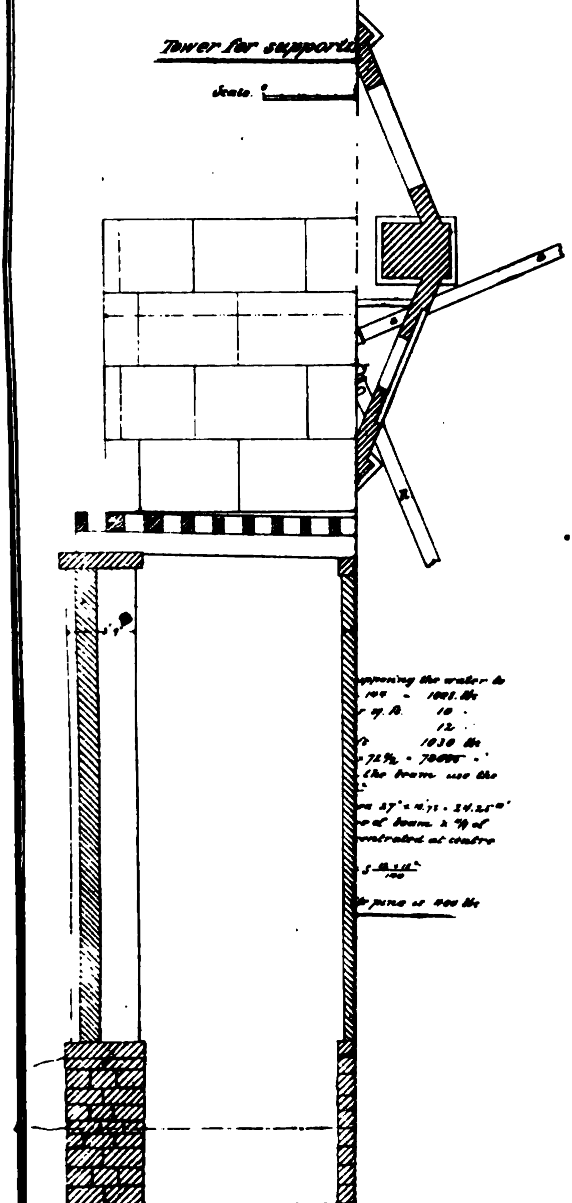
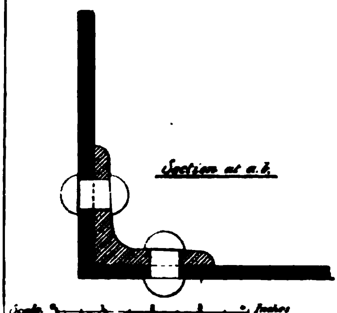


fig. 1.
A
S
fig. 2.
R
A
H
B
E
fig. 3
h

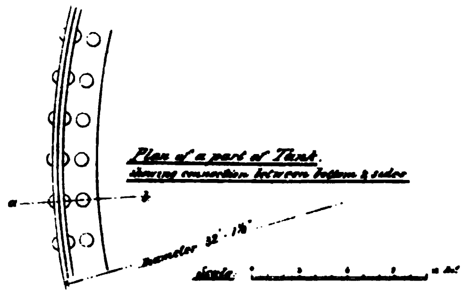
PLATE II




Appendix 9 —1861.

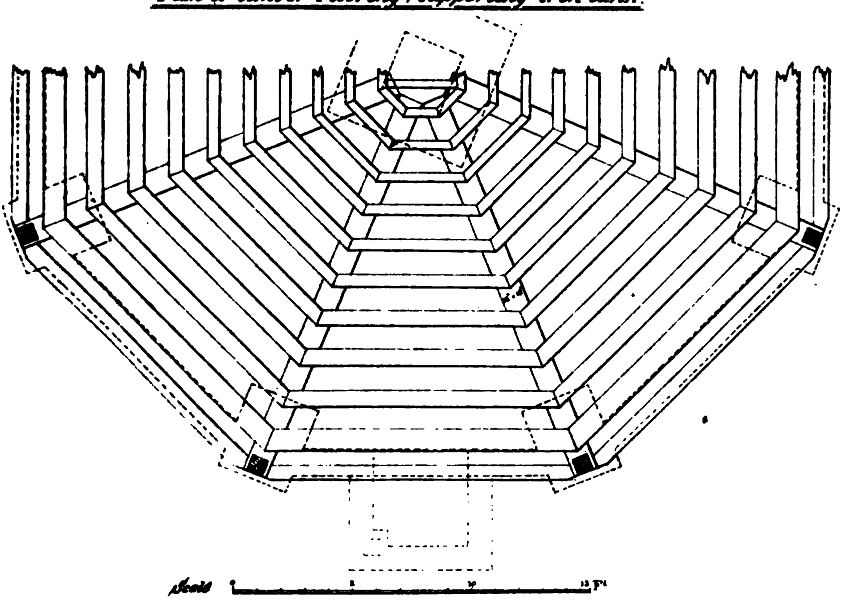


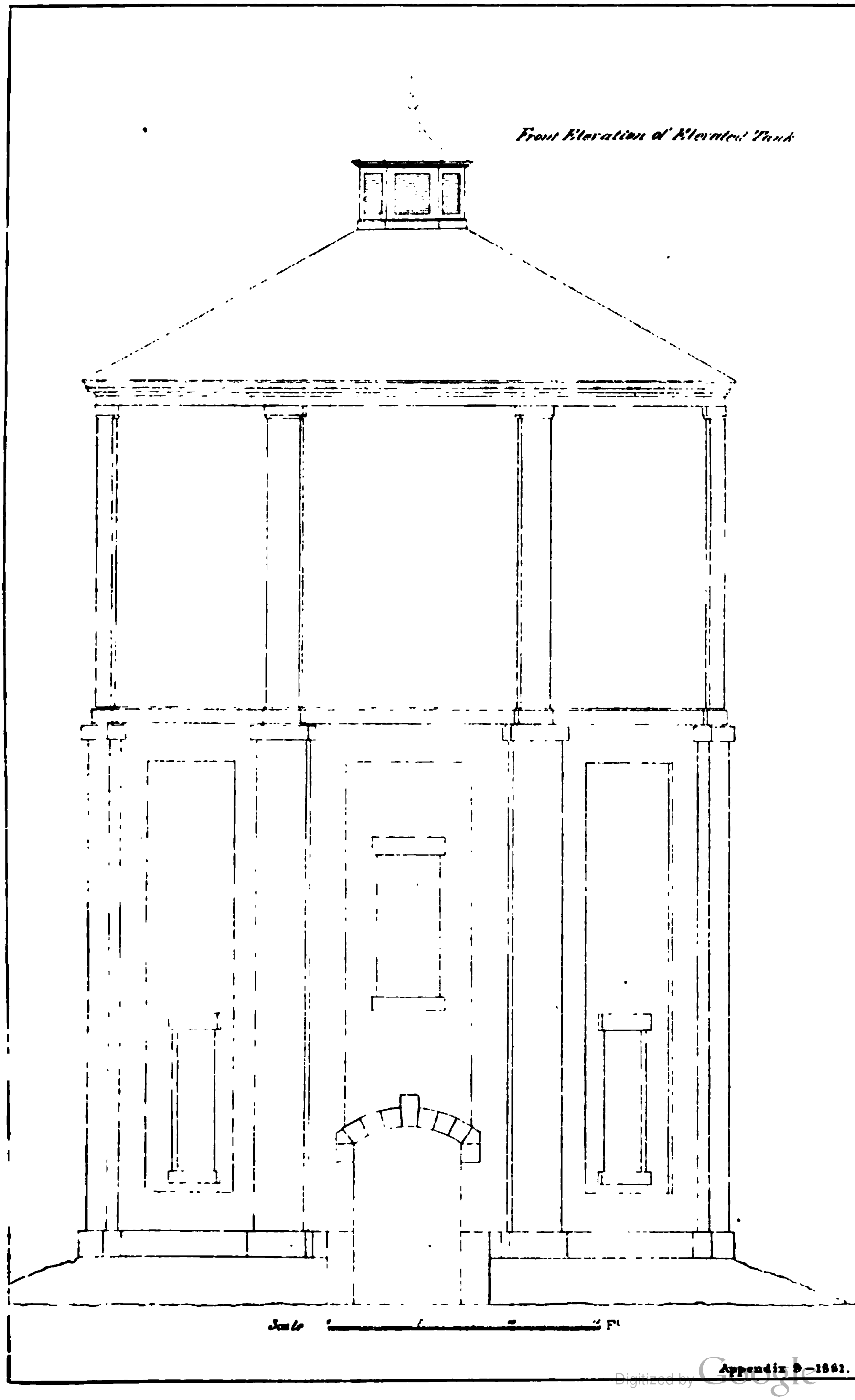

Section at a.b.

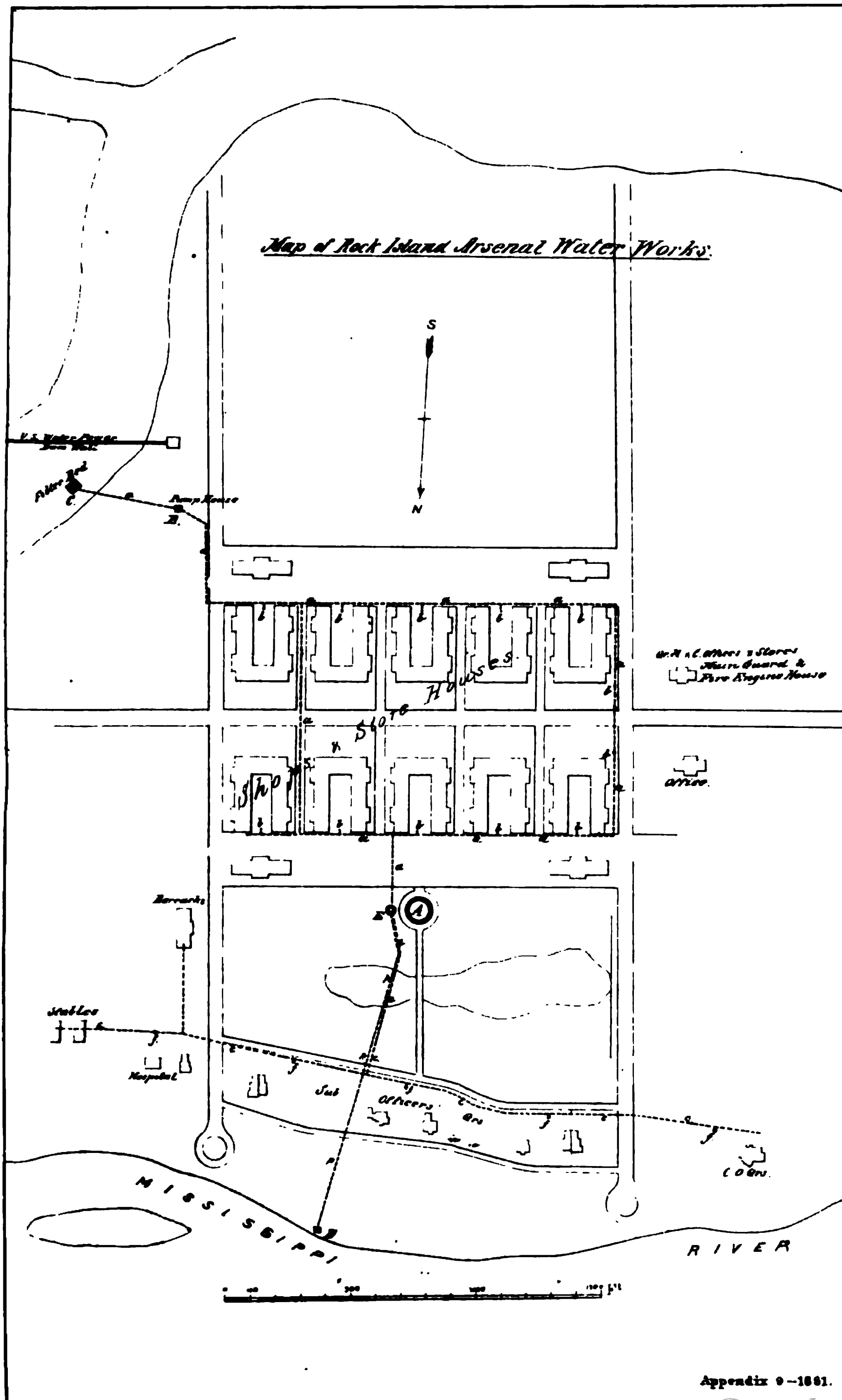



Plan of a part of Tank.
showing connection between bottom & sides

Plan of timber flooring, supporting iron tank.




Front Elevation of Elevated Tank
Scale
Ft


Map of Rock Island Arsenal Water Works.
S
N
Pump House
Barracks
Stables
Hospital
Sub Officers
Shops
Store Houses
Office
R I V E R
M I S S I S S I P P I

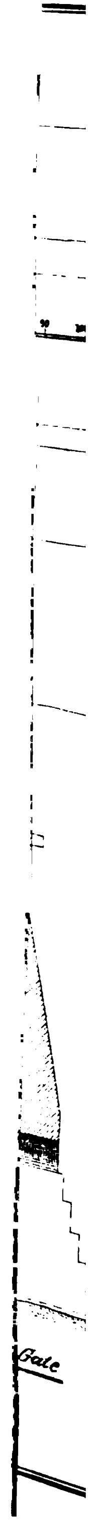
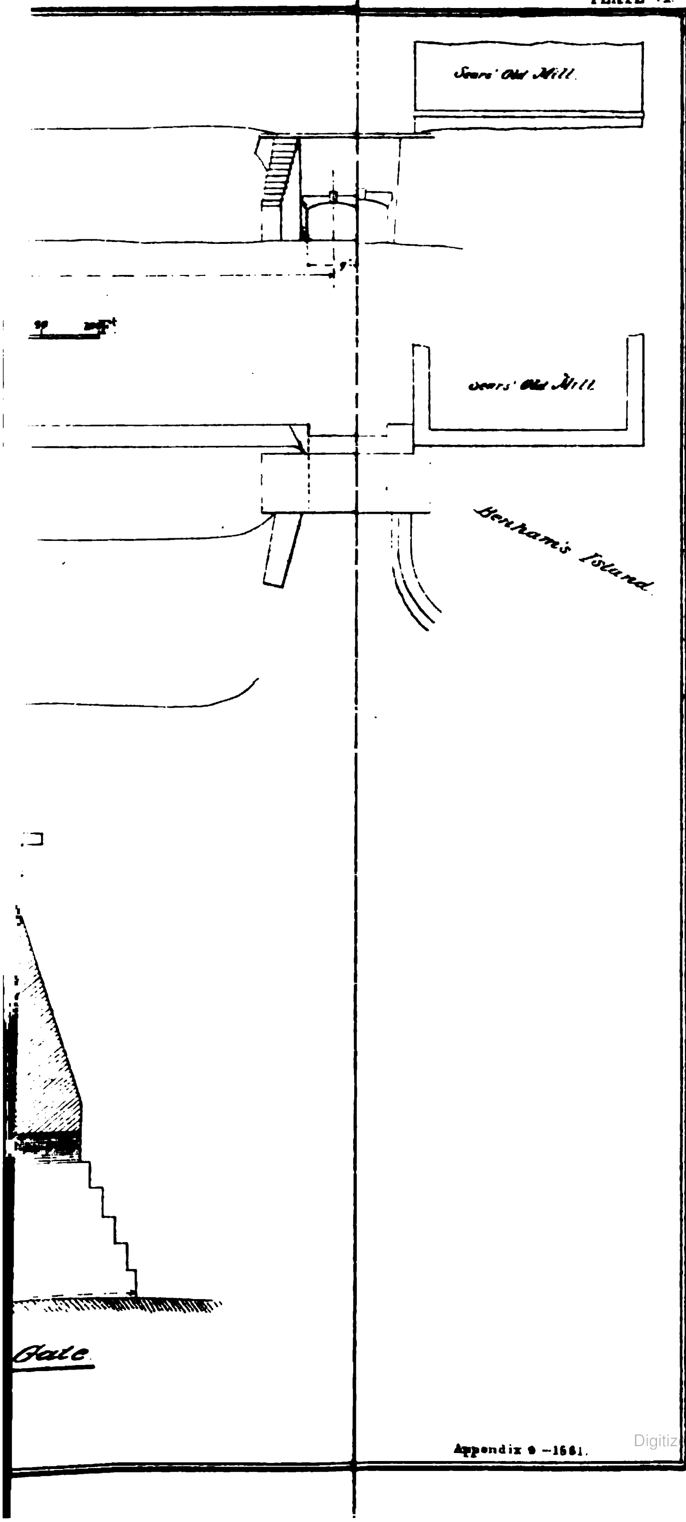
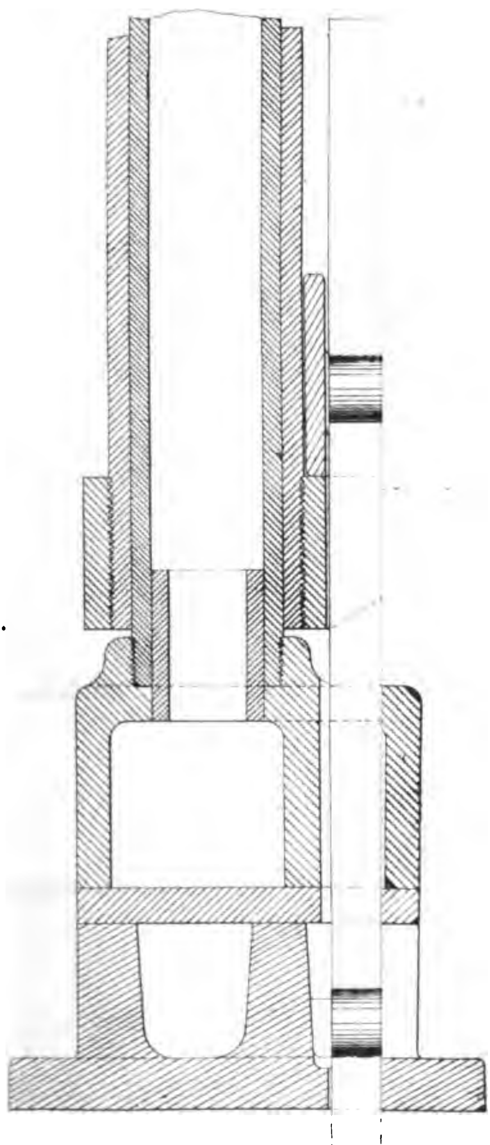


PLATE VI.



## Friction Roller

for



## APPENDIX 10.

REPORT OF THE PRINCIPAL OPERATIONS AT THE BENICIA ARSENAL CALIFORNIA, DURING THE FISCAL YEAR ENDED JUNE 30, 1881, COL JULIAN McALLISTER, ORDNANCE DEPARTMENT, COMMANDING.

GENERAL: I have the honor to submit the following report of the progress made in prosecuting the work at the artesian well at this post, during the fiscal year ending June 30, 1881:

In order to estimate the work to be done when we received the appropriation for this last year, it will be necessary to refer to the time when we discontinued all operations for want of funds.

In March, 1879, we stopped deepening the well. The months of April, May, and June of that year were occupied in making preparations to secure the water, which entered the well at the 960-foot level, for the use of the post. The machinery for boring was cleaned, oiled, and stored, and an estimate was submitted to the Chief of Ordnance for continuing this work, during the fiscal year ending June 30, 1880, of $9,800, but no money was appropriated for this purpose.

Representations were made in April, 1879, in reference to the difficulties that would be entailed on us by the failure of this appropriation. The difficulties resulting from unavoidable accidents have already been numerous, and have hindered the progress of the undertaking enough without any additions from want of forethought or cessation of the work for any period of time. The work must be continuous or its cost is doubled, and if the appropriation for which estimates were made had been granted, there would have been no question as to the advisability of prosecuting the work, as the machinery was in splendid working order, and tools were already manufactured to bore the well to a depth of 3,000 feet, if necessary.

The continuance of this experiment at that time, in the spring of 1879, was of great importance to this region of country, but that necessity no longer exists, as will be shown in this report.

When machinery has been idle and the lining pipes of a well have become immovable in it, nearly half of a moderate appropriation, such as we have been receiving, will be required to place the well in the condition in which it was when work on it was discontinued. This failure, from want of funds to continue the work, has occurred frequently since we first commenced to bore this well, and the government has had to pay for much unnecessary work, because money has not been appropriated steadily from year to year, so that continuous effort towards the progress of the well could have been assured. The pipe-linings of the well, when left stationary for any length of time, became fast in it, owing to the particles forming the wall of the well disintegrating and filling up the small cylindrical space due to the difference of diameter between the bore of the well and the outside diameters of the different sized pipe-casings.

It has been found impossible, in some instances, to pull up wooden piles 60 feet long which have been left one year in soft mud. How much more difficult must it prove to extract over 900 feet of iron pipe which had been fixed in the well hole over one year, the diameter of the latter being slightly larger than the outside diameter of the former.

Experience of these difficulties and the cost of overcoming them made us ask for an appropriation of $9,800, to be expended during the fiscal year ending June 30, 1881 This appropriation met with a better fate than the previous one, as a part of this sum was appropriated for it, namely, $5,000. This was, however, entirely inadequate to the wants of this enterprise, and was too small an amount to justify us in commencing the work necessary to be done. Seventeen months had elapsed since the pipe-casings had been moved, and they formed, with the fillings in of silicious matter between them, one solid mass of stone and iron. It was, therefore, determined not to use any of that appropriation, on the ground that "it would not pay"; and, moreover, we were obtaining substantial advantages from the well in its present condition by using the water obtained from it for every purpose for which it could be employed. The last Congress, however, appropriated an additional sum of $5,000 for this enterprise, and the appropriations for the two years amounted to the sum which was required for pushing this work during one year's time. Therefore, we decided to commence the work late in the year 1880; and then, as the appropriation for that year became exhausted, the money appropriated for the present year's work would be available, and could be used and the work prosecuted continously until the last appropriation was exhausted. The action of Congress in this regard induced us to resign, temporarily, the supply of water we were obtaining from the well, and to attempt to increase it by continuing our work.

Since our last report was written our views in reference to the method which should be adopted to obtain an increased supply of water have been materially modified. At that time we considered it advisable to bore the well to a greater depth, and to sink it below the foul water which entered it 1,405 feet from the surface, and reach a water-bearing stratum below this last. This foul water, as has already been reported, contained too much organic matter to be used as food, and the stench from the gases evolved was very irritating to the lungs. At the time to which we refer the only artesian well besides this one on the western slope of the Sierras was at Stockton, which city is situated in the middle of an alluvial basin of great extent, and its geological surroundings present a striking contrast to those of the hills and cañons of the government reserve, and, also, to the general features of the country lying west of the Mount Diablo range. Therefore, at that time, ours was an experiment, the success of which might influence the prosperity of a large tract of country and its inhabitants.

The dry season here lasts from March to October, and instances of drought are traditional, in which it is reported that the former rulers of this land ordered a portion of their cattle to be driven from a cliff into the ocean and to be drowned, in order to save sufficient sustenance to keep the remainder alive. Thus, if the fact could have been established that artesian water was to be obtained among these hills, as well as on the plains of the San Joaquin, then the dry season of each year would lose its terror to the agriculturist, the stock-raiser, the miner, and even to the manufacturer.

Now, however, the Stockton well and the government well at this point are no longer the only instances of artesian wells in this State, nor in this section of country. Since March, 1879, private enterprise has been developing the sinking of artesian wells through the middle and southern parts of California, and sixteen wells have been bored. We will only give the details connected with a few of them. The results in reference to obtaining good water are the same in all.

The "Davis well," in Ventura County, 6 inches diameter, depth 1,640 feet, furnishes alkali and brackish water. The "San Francisco well," in Los Angeles County, 10 inches diameter, depth 1,513 feet, produces alkali water. From the "Los Angeles well," Ventura County, same diameter as above, depth 1,300 feet, brackish water is alone obtained. A well in San Mateo County, of 10 inches bore and 1,040 feet deep, produces brackish and salt water. The other twelve artesian wells furnish alkali, salt, brackish, and sulphur water. Not one of them produces as good a water as that obtained in the well at this place from the 960-foot level. We can readily perceive that all the water obtained from what are erroneously called "artesian wells" is nothing but surface water which has fallen on the hills and filtered down through the earth, until it has encountered a layer of clay, over which it runs until it finally finds an outlet through these small wells, which vary in depth from 250 to 350 feet. This water contains a great amount of impurities which will in the end, if it is used generally for food, affect the health of the consumers.

From the above, we learn that the question which the government commenced to solve in reference to obtaining artesian water at a great depth has been already decided by the energy of private parties.

Judging from these results, we considered that we might go further and fare worse, and that it was more desirable to preserve the water we had already obtained, and which had proved for the last seventeen months an adequate supply for our wants, than to attempt to obtain new results, for if we deepened the well and obtained another stream of water at a greater depth it would necessarily underlie the water which flowed into the well at the lower level, and it might prove still more impure of itself; or, if we failed to shut out that water from the well, the new supply would most undoubtedly partake of the impurities of the old. Another consideration was the fact that in some instances good water has been lost by deepening a well, and thus opening some subterraneous duct, by which it escaped to a lower level away from the well-hole.

It is very difficult to resign an undertaking in which your feelings have become enlisted and your pride interested, but the above facts were conclusive. We had, besides, anticipations from our former success, which has been before reported, when the water obtained from the 960-foot level rose 2 feet above the surface of the ground, that we might obtain a flowing well by making our pipe tight and allowing none of the water to escape as it passed from its source to the top of the pipe casing.

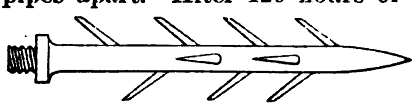
Another expedient, used in the oil regions of Pennsylvania to increase the flow of oil and which we hoped to adopt, might also increase the flow of water, namely, to fire a torpedo or petard at the bottom of the well, thus opening the seams of rock and multiplying the sources from which the water might be obtained. After consulting some practical well-borers who had been accustomed to this work, we determined to employ the last-mentioned means and try to open up the water-bearing seams of rock, at the 960-foot level, and thus obtain all the water which they were capable of furnishing. To effect this, the well-hole had to be cleaned out to a distance of 1,000 feet or more, and a false bottom or bridge built in at that depth to prevent the impure water from mingling with that which flowed into the well above it.

At the commencement of the work there were 300 feet of 7-inch wrought-iron heavy artesian-well casing in it, and at the end of this a brass deep-well pump of 5-inch barrel, which we had been using to pump

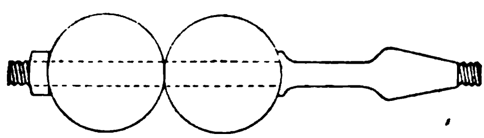
the water from the well, during the cessation of work, for seventeen months; also the 11-inch, 9-inch, and 8-inch casings were in the well.

The anticipation of the difficulty of working in this well, after all these casings had been stationary for so long an interval of time, was not exaggerated. The pipes were glued together, and, in raising the inner pipe, portions of the outer pipes were brought up with it, leaving the walls of the well-hole partially unprotected.

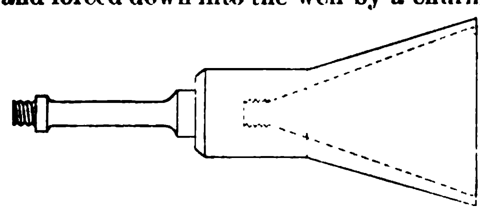
The 7-inch wrought-iron pipe parted in our first attempt to draw it out of the well. We did this by using the clamp described in my last report on the exterior pipe, with two hydraulic jacks for furnishing the necessary power. These appliances parted the pipe before the whole power of the jacks was brought to bear upon it. The only method of taking hold of the pipe, so as to be certain to raise it, was by the bottom; otherwise we would have had to extract it by sections. We employed one of our old tools, before described, and took hold of the bottom of the pipe, employing two 30-ton hydraulic jacks, and raised it by these means one-half of an inch. The power employed, *i. e.*, 60 tons, will convey to the mind an idea of the complete adhesion of the outer surface of this casing to the interior of the other casings in the well. This adhesion being overcome, we raised this pipe the second day, during ten hours' work, 8 feet. On the fourth day, as we drew out the 7-inch tubing, the tops of the 8, 9, and 11 inch casings commenced appearing at the mouth of the well, holding firmly together. All these casings had to be taken out in a solid mass in order to clear the well, and the rivets which held the joints had to be broken, in some cases, to get the pipes apart. After 120 hours of work, five men being employed, we had removed 300 feet of 7-inch, 288 feet of 8-inch, 238 feet of 9-inch, and 39 feet of 11-inch pipe from the well.



When we extracted the last of the 7-inch it was ascertained that the valve and bottom of brass pump had been broken off and were left in the well. The well was then cleaned out with sand-pump until it was clear to the bridge put in 966 feet below the surface of the earth, in March, 1879. A rope spear was then manufactured to extract the bags and canvas which composed a portion of the bridge. In lowering our tools we ascertained that the 8-inch casing had commenced to collapse, and the well began to cave below it. In order to keep the well sufficiently open to admit of the use of our tools, a swedge was made of two 8-inch shells, and this was screwed to the system of rods and forced down into the well by a churning process, pushing back the 8-inch pipe into its position.

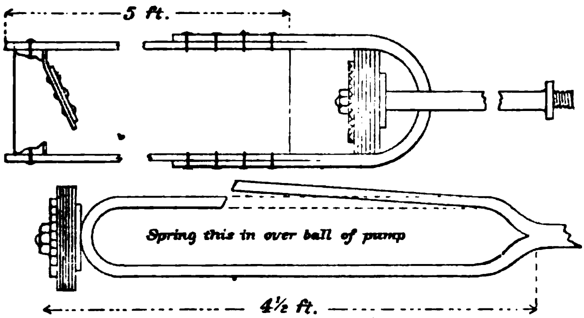


While we were drilling and pumping out the materials which formed the bridge or false bottom, the system of drill rods was unscrewed 200 feet from top of well, leaving the larger portion in well, and we made the following tool, which might be called a bell coupling. The lower, bell-shaped portion of this tool guides the screw-head of the system of rods in the well into the female screw cut in solid head of tool, and the system of rods is turned from above until the new coupling holds

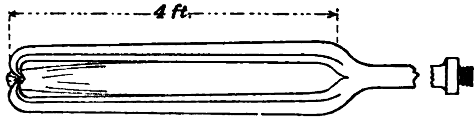


them tight enough to raise them from the well. In removing this artificial bottom, pieces of the brass pump weighing three pounds, and strips of the sheet-iron pipes, were taken from the well. The gunny bags, canvas, and old rope employed in forming this bridge, when extracted from the well, emitted a fearful stench, and we had to use disinfecting fluids and deodorizers, or the workmen could not have remained at work around the well-hole. This proved that, notwithstanding all our precautions, the foul water from the bottom of the well had forced its way up through this mass and impregnated the tissues of these fabrics.

This drilling and pumping occupied five men two hundred hours, and the well was cleared out to a depth of 1,028 feet; that is, 68 feet below the bottom of 8-inch casing. We had to make a new pump to do this work, and in making it we improved on the old pattern. Two hundred feet of 9-inch casing were repaired and replaced by pressure in the well to preserve its walls, and we commencēd to form a new bridge at the bottom of 8-inch pipe, thus making the false bottom 68 feet thick, and using for it cement and sand-rock hammered down. An attempt

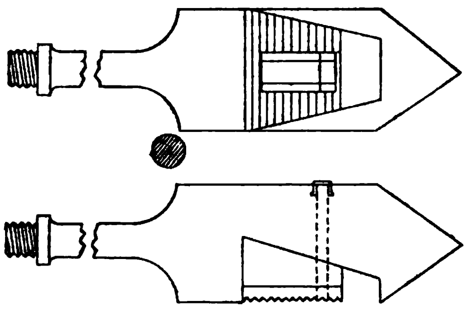



was made to employ a wooden plug, expecting that when it reached its position it would absorb the water and increase in size, so as to entirely fill up the barrel of well and make a hermetically-sealed bottom or bridge between the good and bad water. This wooden plug proved such an excellent absorbent that it became too large before it reached the bottom of 8-inch pipe, and was immovable. We broke it in pieces, after losing sixty hours work by our failure, and thus cleared the well. In pumping the well out we met with several accidents, on one occasion leaving the pump in the well, and in




order to extract it we made a tool, which might be called a sand-pump hook. The latter consisted of three prongs, each a spring with points turned inwards at the bottom. By pressing this down one of the prongs would catch the ball of the pump, and, once caught, the latter could not escape from the grasp of the tool, on account of the position of the hooks at the end of the other prongs. We had to raise some of the interior casings to repair them, and in order to do this we made a new tool, calling it a casing spear or pipe extractor. This tool was circular, and the holding part was a wedge the circular surface of which was serrated. The wedge worked vertically, having a slot in it and being confined to the tool by a bolt passing through the slot in wedge. When the tool reached its position in the pipe to be raised, the wedge slid down as the tool was raised until the bottom of wedge rested against the shoulder of the tool and acquired a fixed position. The new position of the wedge increased the diameter of the tool, and the serrated edges of the

circular surface of wedge were forced into the pipe. The hold thus obtained on the interior of pipe enabled us to raise it from well. The

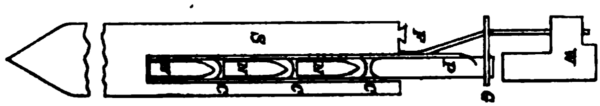


bottom being formed, we attempted to make well-hole true and to force out the sides of pipe which had collapsed, employing for this purpose a swedge 7¾ inches diameter, but we found we could not force this down below 720 feet. We, therefore, reduced the size of this tool to 7⅝ inches, and finally succeeded in putting it through 8-inch pipe.

Preparations were then made to carry out the the design of exploding a cartridge in well-hole and putting in a pipe with hermetically-sealed joints to keep the water from escaping before it reached the surface.

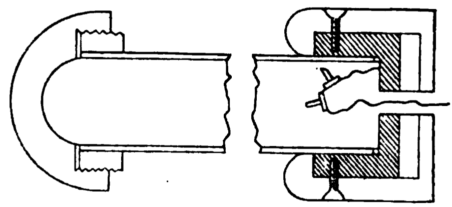
In selecting our explosive for the torpedo we had to consider the following facts, namely, that no common carrier would transport nitro-glycerine in its liquid state, and that to manufacture it here would be too expensive; therefore we concluded to use some of its dry compounds, which were less explosive and which the railroad company was willing to transport. This determination would seem an immaterial one, but it involved much more trouble than we anticipated. When nitro-glycerine is used the cartridge-case is filled with a liquid and the outward pressure against the inside surface of the cartridge-case is equal to that of the water on the outside of it.

In resolving to employ a solid explosive we had to prepare a cartridge-case strong enough to resist 450 pounds pressure of water to the square

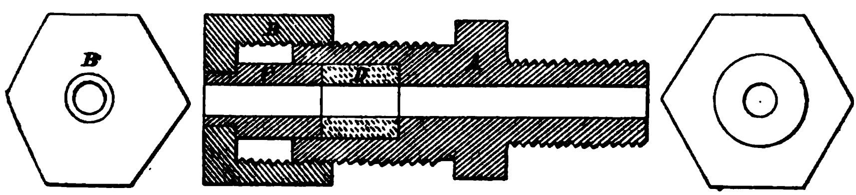


inch, and the material used for it, with its joints, had to be impervious to water under such a pressure. We made a cartridge-case of heavy tin, such as is used in the oil regions of Pennsylvania (see accompanying sketch), S being the cartridge-case; F, funnel for charging shell; P, plunger; G, guide; N, small steel hammers; C, percussion caps; W, weight to drop from above down steel wire, which impinges on plunger and fires caps by means of the three steel hammers in fuse free to move vertically. We tested this case by filling it with well-rammed dry sand and immersing it to the proper depth in well. On withdrawing it we found that the outside pressure had been great enough to bend in the sides, and in several places the water had burst open the seams, and the sand which filled it was perfectly saturated with moisture. While we were fabricating another cartridge-case, 900 feet of 2-inch pipe was screwed together on the ground and tested as to whether it would stand the pressure of the water in the well at a great depth. A cartridge-case was made of a 4-inch wrought-iron water-pipe by shrinking two wrought-iron rings on its extremities; threads were cut in these, and a cast-iron bottom was made to screw on to barrel. The top was of brass and confined by a wrought-iron clamp tightened by thumb-screws. India-rubber gaskets were placed where the top and bottom touched edge of pipe. The brass cap was perforated in center for water-tight fuse-plug, through both of which the insulated wire passed. This cartridge was loaded

with 25 pounds of the highest power of dynamite, and 7 pounds of rifle powder, the latter confined in an oiled-silk cartridge-bag and placed on top of the dynamite. The two Frankford magnetic primers, connected by a wire, were inserted in the rifle powder, and the edges of the oiled-silk silk bag brought firmly together over them and tied, and one of



the wires from the primers being connected by means of a second wire with a metal button on the under side of the cartridge cap. The insulated wire from the other primer passed up through the water-tight fuse-plug to the top of the well, and the cartridge was lowered by a steel wire rope to its position. Another steel wire was weighted with a large piece of iron and lowered about 100 feet in the well. The wire, with weight, was attached to the steel wire rope, by which we lowered the cartridge, and the magnetic wire was fastened to this last, and attached to the nearest pole of the battery, which consisted of twelve cells. The insulated wire direct from the cartridge, which passed up through the water, and a wire attached to the further end of the battery were led some distance outside of the well-house. At a given signal, when all was ready, the ends of the two wires were brought together and the contents of the cartridge was exploded. The effect of this explosion was scarcely heard and not felt at all at the mouth of the well, but a sensible shock and trembling was experienced at the old shops near the wharf and at the officers' quarters, and even at the garrison, Benicia Barracks, on the hill. A large amount of gas appeared at the well hole on the surface of the water, and the displacement of subterraneous strata must have been very great. The fuse used, which proved perfectly water-tight, deserves



*A. Brass plug.*
*B. Brass cap.*
*C. Brass tube or packer extending through cap B.*
*D. Rubber tube for packing cable.*

to be described here. It was made of brass and consisted of two parts, a shank and a top. The latter was screwed into the top of the cartridge-case, with a shoulder, which pressed against an India-rubber gasket between the bottom of the shoulder and the top of the cartridge-case, when the fuse was screwed into position. There was an interior shoulder to the shank of the fuse, on which rested an India-rubber cylinder. A brass inverted cap was screwed on to the outside of the top of shank, compressing the India-rubber cylinder, so as to fill up the whole space left between the sides of the shank and the insulated wire which passed up through shank, India-rubber cylinder, and cap, the cross-section of this cap being an octagon.

We have been occupied ever since in cleaning out the well, and cannot prophesy anything at present in regard to any permanent advantage which may result from our experiment, although there is a greater amount of gas obtained, and, we hope, purer water.

## APPENDIX 11.

### REPORT OF PRINCIPAL OPERATIONS AT THE PICCATINNY POWDER DEPOT DURING THE YEAR ENDING JUNE 30, 1881, MAJOR F. H. PARKER COMMANDING.

In order to make intelligible and to present in a consecutive manner the operations carried on and the work accomplished during the fiscal year, it is necessary briefly to refer to the condition of affairs connected with the establishment of this new ordnance post previous to July 1, 1880.

After searches and examinations of tracts of land for the establishment of a powder depot situated on the various railroad lines and waterways around New York had been reported on, a board of officers was appointed, November 7, 1879, to decide on the most suitable one. Owing to delays in the proceedings of the board and to time occupied in vain efforts to secure tracts on the Hudson River with the small appropriation which had been given for the purchase of land, the selection of this tract was only made and approved March 16, 1880, and negotiations for its purchase immediately commenced. The consent of the State legislature being required, and the end of the legislative session being near at hand, it was necessary, in order to save the appropriation from reverting to the Treasury at the end of June, to close in haste the bargain with the owner of the larger part of the land, the price of which regulated that of the other portions, and to secure without delay the passage of the act giving the consent of the State to the purchase. A longer time to act in would, doubtless, have obtained the land at a less price.

On the 1st of July, 1880, an appropriation of $50,000 became available, $18,500 of which was allowed to be expended for additional land. There was actually so expended $17,750, leaving a balance of $32,250 of the appropriation to pay expenses of searching titles, surveying and mapping tract, closing old town roads and opening new roads, making plans and drawings, commencing first magazine and all expenses incident thereto, including additional buildings for storage, shop work, and quarters for employés, and for tools, implements, horses, and vehicles.

No work could be commenced until the purchase of at least a portion of the land was fully consummated and the title vested in the United States, although the agreement to buy it was made and the searches of title required by law were in progress. The delay and expense occasioned by the Department of Justice in searching and passing upon the titles of the five different properties of which the whole tract is composed was far beyond what was anticipated. It was only on the 15th of March, 1881, about a year after this tract was selected and negotiations were first opened for its purchase, that the legal formalities were terminated and the last of the purchases was pronounced ready to be completed by the payment of the purchase money; meanwhile, there being no absolute certainty that the different titles undergoing scrutiny would be found entirely satisfactory, operations were in consequence more or less impeded.

The survey of the tract was commenced March 30, 1880, the work of which was laborious and slow, owing to the rough and difficult character

of the country over which the lines were run; steep, rocky mountains, valleys, streams, lake, thick woods, and brush intervened, and the greatest difficulty existed in finding old corners; when they were found and agreed upon by the adjacent owners, they were accepted and run to, but where they could not be found the lines were run by the old deeds, such allowance being made for the variation of the needle as was found to exist on those courses where the old corners were undisputed. The tract is irregular in shape; there are many sides; some of the courses are long, and the distances seldom agreed with those given in the old deeds, the surveys for which were carelessly made, so that altogether it was a vexatious and slow operation to complete the surveys of the different properties, make them close, inclose only the land to be purchased, calculate the areas, and satisfy the owners. Maps of all the separate purchases were made for file, and were furnished to the United States district attorney for use in searching titles; also consolidated maps of the whole tract. These, however, were only outline maps, and it was necessary to proceed to the work of making a detailed topographical map on a large scale which would be permanent and of the greatest value in the future in building up the post. Field work on this was continued while the weather permitted, and work on the map in office during the winter, when other more pressing work allowed. The most important part of the map is finished, but some work is yet to be done to complete it. The surveys and maps, as well as the drawings pertaining to the buildings, were made by Mr. H. N. Babcock, civil engineer.

A general plan of the depot composing the future location of the buildings, roads, &c., was submitted and approved, to be worked in the future, subject to such changes in details as experience might show to be advisable.

Before commencing work, it was necessary to procure a plant of tools, implements, draught-animals, vehicles, &c., and to put up structures in which to live and to work and to store materials.

*Accessory buildings.*—The farm-houses and other buildings on the place were of the poorest description, old and dilapidated; they have, however, all been in use. A small frame office, a small store-house, tool houses, blacksmith shops, and a dwelling-house for the superintendent of mechanics and laborers have been built. An old building has been turned into a carpenter shop and lumber store-house. The stables and other buildings have been repaired and some of the poorest torn down and removed. The most expensive and important of those built is the quarters for the superintendent. It was at first intended to repair the best of the farm-houses for the purpose, but upon examination it was found that little would be saved by the attempt, and that only at the loss of comfort and convenience. It therefore became necessary to build anew, and a plain but convenient frame house has been built, which will furnish comfortable quarters for the occupant and his family. The estimated cost was $1,500, but owing to the extremely severe winter weather, unfavorable to any kind of building work, it considerably overran that sum, and took much longer to build than was anticipated.

*Roads.*—The plans anticipate the building of miles of new roads through the grounds, and the repair and improvement of miles of old road. But only so much of the old road was improved as was necessary to facilitate hauling, and the only new road built was about one and a half miles to the quarries. The old road was improved by clearing out bowlders and stones, ditching and building small culverts and bridges where needed, and making the road-bed with a thick layer of gravel. About two miles of this was completed, but in time the bed

will have to be widened. The new road was built in the same manner, and although wide enough for present use, will also have to be widened. To shorten the distance of the drive to and from Port Oram and Dover, and thus facilitate and cheapen the hauling of material into the powder depot, it is designed to build a wagon-road on the east side of the valley to the Dover turnpike, passing a distance of more than a mile through adjoining property. Negotiations for the right of way were opened, and after considerable difficulty and time it was obtained, and a strip of land 50 feet wide was secured for the purpose of a road. The road will be built by degrees as time and money permit. It was also part of the plan to close a town road running through the middle of that part of the tract reserved for magazines. This required compliance with the State law in such cases made and provided, viz, a petition to the county court of ten freeholders of the town, posting notices, advertising the proposed closing of the road for a period of ten days, ordering by the court a survey by the town surveyors, posting their favorable decision, and its filing in the county clerk's office, all of which was done, the road vacated and made a private road entirely under our control.

*Railroad.*—The remoteness of the powder-depot tract from rail or water communication was the principal objection to its selection, and the selection was made with the understanding that we should build a branch railroad to Port Oram, a distance of three miles, to connect with the Delaware, Lackawanna and Western Railroad, the High Bridge Branch of the Central of New Jersey, and with the Morris Canal, thus giving complete rail communication in all directions for receiving and issuing all building material and powder.

During the winter a proposition was made by responsible railroad men to build a road from Port Oram through the powder-depot land to connect with the Midland Railroad of New Jersey, and by it with other northern roads, provided some assistance would be given by the United States. It was proposed by them that one-half of the expenses of building the road through the government land should be borne by the United States, in consideration of which they were to build and operate the road, giving the United States certain privileges. The carrying out of this would have been of the greatest value to the powder depot, and a saving of expense to the government. The scheme was submitted and efforts made to get the necessary appropriation from Congress, but were not attended with success. If no railroad is built into the powder depot, its value to the service will be very much diminished, and the building up of the post will be slow, laborious, and costly. If the government itself builds a branch from Port Oram, it will necessitate a considerably greater expenditure than required by the above scheme; and if a railroad company should build a branch in at its own expense to take our freight, its rates will necessarily be very high, and it will at best be but a poor substitute for the through line.

*Grounds.*—Clearing land of timber and brush has progressed to a limited extent; the unusually severe winter weather almost suspended out-of-door labor, and the deep snow was unfavorable to a proper prosecution of cutting timber. About 50 acres have been cut off on the magazine part of the reservation, but the stumps have not been grubbed nor the brush cleared away; some old ditches for draining have been cleared out and new ones cut, but the draining to be done in the future is a work of considerable magnitude. About 30 tons of hay were cut, made, and stored last summer, which has gone far toward feeding the public animals during the year, and this year sufficient corn and oats have been planted to supply our wants in that respect during the com-

ing year. Many acres have also been seeded down for meadow land. Twenty-two masonry monuments, to permanently mark the boundaries of the government tract, have been built at the principal outside corners, which, in some cases, was a work of considerable difficulty, it being necessary to carry material on mule's back to the points on the mountains inaccessible by other means of transportation.

*The magazine.*—Plans and drawings of the magazine were made in this office and approved by the department. On the 16th of September, 1880, a part of the land having been purchased, work was commenced in digging the foundation of the first magazine. The building being 200 feet by 50 feet in plan, with a 6 feet basement, considerable excavating was required. After having cleared to the depth of about 7 feet, the question of the security of the foundation arose and necessitated deeper searching into the substrata to determine their character and ability to prevent settling. Having no arrangements for boring, recourse was had to digging some 20 feet to water, and until it was found that by going lower we would be no more secure, unless a false foundation of concrete and stone was laid at great expense. Moreover, it was decided that the stratum of hard gravel which had been found at a depth of 7 feet, and which varied in thickness from 5 to 8 feet, having underlying it thin strata of sand and thicker strata of gravel, would, if the foundation walls and piers were spread out, prove sufficiently stable. Therefore 3 feet below the cellar floor on this gravel bed the subfoundation walls and piers were spread out to 6 feet, upon which the 3 feet foundation walls and piers were built.

The foundation of the building to and including the water-table is of stone quarried on the ground. The Green Pond Mountains are composed of a conglomerate or pudding-stone peculiar to them, and found nowhere else. Glacial action has distributed its bowlders over a considerable extent of country, as far east as the Hudson River, and it has been used to some slight extent in building at different places, making a showy and durable structure, and it was the intention to use it for this foundation, more particularly because great quantities of it are found as loose *débris* along the foot of the mountain, in all sizes, from small blocks to large bowlders, and it was thought that, being so conveniently at hand, it could be inexpensively used. We therefore selected a near convenient spot, and commenced getting out the loose stone and laying the subfoundation. But a certain amount of trimming, splitting, and cutting was required, even for this rough masonry, and it was very soon found that the attempt to work it ever so roughly was laborious and expensive, and that for any part that required regular dimensions it was entirely unsuitable. It was, therefore, necessary to prospect for an easier-worked stone. It was known that granite cropped out in some few spots on the reservation, and after search a ledge of it was found on the opposite hills, which, although hard to cut, turned out to be suitable building-stone. Two quarries were opened about a mile from the magazine, and roads built to them. The conglomerate was abandoned and considerable stone was taken from out these quarries, and hauled and built in the foundation, and a good deal cut for corners, sills, and door jams. The stone was laid in pure cement mortar, part Rosendale and part Saylor's anchor brand, from Allentown, Pa., where, after a careful examination of the cement market, it was found that a suitable article could be procured at lowest rates. The work continued under these disadvantages until the 1st of December, when the cold weather put a stop to it, and, although it was desired to continue cutting stone during the winter, and would have vastly progressed the work if we

could have done so, the small amount of money left, and the necessity of providing for demands upon it expected to arise before the end of the fiscal year, obliged me to discontinue all stone work. It was, however, thought advisable to contract for during the winter, and have delivered during the spring, the iron work completed for the building. This consisted of floor-beams, ceiling-beams, columns, roof trusses, doors, windows, &c., all made up ready to put in the building. Drawings were therefore made of the details of the iron parts, proposals advertised for, and the contract awarded to the Passaic Rolling Mill Company, of Paterson, N. J.

There was laid 8,500 cubic feet of foundation; and 458 cubic feet of stone was cut for the water-table and other trimmings. It was the intention to concentrate the money on the magazine as much as possible, and to push that at the expense of everything else, and it is regretted that the building could not have been further advanced, but circumstances were adverse, and other matters imperatively demanded attention and expenditure of money.

In the spring, on the 4th of May, we recommenced hauling stone from the quarries, and on the 1st of June, we recommenced cutting, and have continued both to advantage since. The iron work was delivered at Port Oram according to contract, and hauled by us to the magazine from time to time as it was completed and inspected. It is therefore now on hand, as well as quite a supply of cement and a large quantity of stone on the ground, and a good deal of the dimension stone cut; and it is hoped that we shall be able to cover in the building this season, notwithstanding the usual vexatious delay of being obliged to wait till the middle of the working-season for funds with which to prosecute the work.

## REMARKS.

The result of this year has been to give us a good start in the work of building the powder depot, and its experience has been rich in developing a knowledge of facts for our guidance. Perhaps the most salient of these facts is the utter inadequacy of so small an annual appropriation as $50,000 to economically and vigorously prosecute the building up of a powder depot in this locality. The work is of a costly nature, and so small a sum can go but a little way toward forwarding the work to completion. As far as I can judge, it will mostly be expended in a few months, and the work will have to lie idle the remainder of the year. The expense of overseeing, &c., and of the permanent force necessary to be kept throughout the year, is as great for the small amount of work done during these few months as if a large force was at work during the whole year.

Besides building the large magazine store-houses and other necessary accessory buildings, there is a great deal of work to be done to put in proper condition, beautify, and keep in order the extensive grounds. Miles of roads are to be made and fences and walls to be built. Acres of land are to be drained, both by ditching and laying underground porous tile drain-pipe. The brook running through the valley should be straightened, and at its outlet from the valley, where it is pinched up and obstructed, it should be blasted out and widened. A comparatively small expense here would reclaim much of the swamp land and change the whole character of the valley. Much land is to be cleared, and some low land which cannot be drained should be filled.

The water-power from Green Lake and Denmark Pond should be purchased with what little land is necessary to properly develop and arrange

it for powder mills, and work should be commenced toward beginning the establishment of a small experimental powder factory. But paramount to, and of more immediate necessity than all these wants, is the want of a railroad to facilitate, expedite, and cheapen the operations to be carried on both in building and for future use of this depot of supplies. My annual estimate herewith shows what work in my opinion should be prosecuted next year.

The establishment of a powder depot in this remote spot is in the nature of an experiment; it may be made a success and a credit, or it may easily be made a failure and a discredit to the department and a reproach to those who located it. In order to compass the former and avoid the latter result, liberal appropriations and active interest should sustain the efforts of those having immediate charge of the work.

## APPENDIX 12.

### REPORT OF THE PRINCIPAL OPERATIONS AT THE FRANKFORD ARSENAL, PENNSYLVANIA, DURING THE FISCAL YEAR ENDED JUNE 30, 1881, MAJOR S. C. LYFORD, COMMANDING.

[Seven plates.]

#### MISCELLANEOUS OPERATIONS.

The most important miscellaneous work done during the year embraces the following:

3,528 square yards of walks and roads covered with gravel and broken stone.

1,574 square yards of grass grounds graded and renewed.

378 square yards of brick pavement laid and repaired.

The outside and inside of many of the public buildings have been painted, from one to three coats, as was necessary in each case. Reduced to one coat, the whole surface covered amounts to 12,725 square yards. This includes the following buildings:

The married soldiers' quarters.

The first sergeant's quarters.

The hospital.

The niter store-house.

New and old fences have been painted when necessary. The whole surface covered, reduced to one coat, equals 3,499 square yards.

Indispensable repairs to the woodwork of the buildings have been made.

346 square yards of new fencing have been erected.

127 square yards of wood ceiling put up in paint shop.

314 square yards of sheds for coal, &c., built.

162 feet of iron sewer pipe laid.

627 feet of terra-cotta sewer pipe laid.

1,837 feet of iron water pipe laid.

160 feet of lead water pipe laid.

1,197 feet of gas pipe laid.

250 feet of steam pipe laid.

The fire apparatus and regulations have been overhauled.

In this connection, the keys of all buildings have been arranged on racks, and labeled, so as to be readily accessible to watchmen, and the doors of buildings correspondingly marked, to facilitate operations in case of fire at night.

22.951 cartridges have been fired in test of daily work, inspection of powder, and experiments generally.

No casualties of any importance occurred.

The shop fixtures, elevators and other appliances, have been overhauled and repaired.

A wind vane, anemometer, and self-registering anemograph have been put in position, and electrical connection established between them.

The office, shops, and proof house have been connected by telephone, and electrical call-bells put into the office, storehouse D, guard-house,

&c., all of which are valuable aids to the prompt and easy execution of public business.

Shields and masks have been provided for the target range to stop stray bullets, and render the experimental firing safer, and less liable to interruption.

The quarters lately occupied by the first sergeant have been altered to accommodate four families, giving three rooms to each; and assigned to married soldiers.

A portion of the ground in rear of the hospital has been fenced in, to form a yard, and an earth closet erected therein for the use of the hospital steward and matron.

The stables have been altered to provide for the three horses sent from Washington arsenal; and the facilities for storing forage enlarged and improved.

A small frame building has been removed to a position west of the space between the machine and loading shops, to serve as an office for the officer in immediate charge of the shops.

The officer in charge of ballistic work has his office in the proof house.

The city water has been introduced into the following buildings, and the necessary connections made with the main water pipe running through the grounds, and the system of sewers, and the latter has been extended and improved:

All the officers' quarters.
The office building.
The chief clerk's quarters.
The hospital.
The blacksmith shop.

Some alterations have been made in the grounds, so far as the situation of the walks, roads, and grass surfaces are concerned, which it is believed adds to their beauty, and decreases the expense of keeping them in order.

These changes were undertaken principally with a view of utilizing material, gravel and brick, which in their old positions were of little use, if any.

By taking up the bricks about the two main store-houses, a sufficient number of good ones were obtained to repair all of the old walks; and by the gravel and metal obtained from the roads discontinued, and the roads renewed, the remaining roads, to a great extent, have received a much-needed covering.

The parts formerly in brick and gravel have been sown with grass seed, presenting a pleasing appearance to the eye, and in a year will be covered with a strong, firm sod.

Sketches are appended illustrating these changes.

### ENLARGEMENT OF SHOP SPACE.

During the year one of the iron-frame laboratory buildings has been moved to a position north of the carpenter shop, and west of the blacksmith shop, to provide an extension to the former, with roofed space between to permit the passage of a cart. This gives a separate room, free from the noise and interference of the wood-working machinery, for pattern-making and other special work.

A second iron-frame laboratory building has been moved to a position east of the loading shop, and all hand operations of assembling paper boxes, and packing the cartridges, &c., therein, transferred to it.

The space thereby gained in the loading shop has been filled with the machinery for paper boxes, transferred from the second floor of the

machine shop, leaving in the latter only the machinery for cartridge operations up to that of loading friction and electric cannon primers, and printing-presses and material.

In consequence, the supervision of paper-box manufacture has been transferred to the foreman of the loading and packing shop, with increased convenience and economy of labor and material; while relieving the foreman of the cartridge case and primer shop of that duty, and enabling him to devote his entire attention to the details of his proper division of the work.

A heater for feed water has been procured and connected with the boilers of the shops, and a pump put in to replace the injectors.

These appliances are in satisfactory operation, and will effect an economy of from 15 to 25 per cent. of fuel.

A chain pump has been erected over the well into which the condensed steam from the engine flows, to keep it clear by discharging the water, the ground having failed to absorb it, as was originally intended.

A small annealing furnace and retort have been erected, to anneal a limited product of cartridge cases, with economy of fuel and other material.

A crucible furnace has been arranged, and other facilities provided for making small brass castings, using scrap metal from cartridges, &c., with economy and convenience.

About one-third of the basement of the machine shop has been partitioned off to form a store-room for miscellaneous shop supplies, where the articles, being readily accessible to the workmen, are only issued in quantities sufficient for their immediate needs, by the storekeeper, who keeps a record of the purpose they are intended for. In his other capacity as timekeeper he has a desk in this apartment, and it is here the bulk of the records of the shop order system are kept.

The gas-pipe system of the shops has been extended and overhauled with a view to working ten hours daily throughout the year. If the experiment of making cartridges by gas-light succeeds, I purpose recommending the purchase of apparatus for generating gas from gasoline, and have gathered already much information on the subject.

During the year an offer was made by the contractor of the engineer office in Philadelphia to supply dredging from the river for filling the lower grounds of the arsenal, and deliver them upon the creek embankment free of cost; but owing to the weakness of the wall and embankment, it could not be made available.

The present creek wall is of loose stone, built upon the mud bottom of the creek, and for years past estimates and requests for an appropriation to rebuild it in a more substantial manner have been submitted.

It is constantly in need of repairs, and is a drain upon the moneys that could be better expended otherwise. Steps are being taken to improve the Frankford Creek, in the interest of the manufacturers hereabout, and as it has been impossible to get an appropriation of the whole amount necessary for a new wall, I have this year asked for a small sum, in the hope that a beginning may be made upon the work. If funds are allowed for this purpose, I propose to build a stone wall upon a foundation of piling, sunk below low-water mark, and by doing a little of the work yearly, in time renew the whole.

## DESCRIPTION OF DARLING, BROWN & SHARPS' LEAD FURNACE AND MACHINE FOR HARDENING TOOLS.

The machine is designed to counteract the repulsion between heated metal and water, by giving the latter sufficient motion to overcome the

repulsion, and insure the perfect hardening of the tools when immersed in it.

The machine shown in the accompanying drawing (Plate I) consists of a cylindrical casing, C, inclosing two smaller cylinders, A and B. These have vertical shafts with wings and outlets similar to the ordinary power fan. The casing C is filled with water. The shafts D and E are driven by gears with the shaft Z in opposite directions, causing the water from each to impinge at O with force according to the speed. Into the vortex at O the tool is plunged when heated to the proper degree, and is more thoroughly and perfectly cooled and hardened than by the ordinary means. In connection with the machine is a furnace (Fig. 1) for heating the tools to be hardened, by means of molten lead in the pot X. The lead is heated to the desired degree, and the tool immersed in it until it is heated throughout. The lead being uniform in temperature, the tool is more evenly heated, and hardened better than by other means.

### SAND-BLAST PROCESS FOR SHARPENING FILES.

This mode of sharpening files was introduced at this arsenal in April, 1881. The apparatus is shown in the accompanying drawing (Plate II).

The file shank is secured in a pair of tongs, A, which travel on a guide, B, attached to the steam pipe C. Steam is admitted to the branch pipes D and E, which are inclined to the surface of the file. The rubber tubes F and G connect them with the sand box P. The steam draws the sand up through the tubes, and drives it against the file teeth. The file is kept in motion back and forth to distribute the force of the sand, and uniformly sharpen the teeth. From six to ten dozens of files can be sharpened by an expert hand in one day. Fuller details are given in the annexed circular of the manufacturers.

### THE FRANKFORD ARSENAL MACHINE FOR HEADING SOLID-HEAD CARTRIDGES.

This machine is shown in three accompanying drawings (Plates III, IV, V, Figs. 1, 2, 3, and 4).

The improvements it embodies on the machine for folded-head cartridges, are:

1. A heavy frame where the line of strain is below, not on top of the frame.
2. The bearings are cast solid to the frame.
3. The use of keys X, Fig. 3, to support the heading bunter H and the punch B, to relieve the thread of the screw on the holder of strain, and consequent yielding and wear, due to pressures of from 30,000 to 40,000 pounds, 65 times per minute.
4. The arrangement of a fly wheel on each side to equalize the work, and transfer it through the crank pin.

All parts of the machine are made heavy and strong, and with special reference to the area of wearing surfaces. The pressure is so distributed that a cast-iron connection on the crank is used with better results than any other metal. No adjustments are used, except at the bunter.

To secure a head concentric, and of uniform diameter, the heading die to Fig. 2 is recessed to the minimum thickness, and a fin or bur is made on the headed shell K, Fig. 4. This is afterwards trimmed by a special tool shown at N, Fig. 4. This feature is new, and gives a correctness of form not otherwise attainable.

The very small limits allowed for thickness and diameter of head require strict attention to tools and to the operation of forming the pocket, which is done on an ordinary heading machine, and constitutes a separate special operation introduced at the arsenal to perfect the heading operation.

### THE FRANKFORD ARSENAL PRIMER-INSERTING MACHINE FOR SOLID-HEAD CARTRIDGES.

This machine is shown in the accompanying drawing (Plate VI). Its principal features are a carrier wheel, P, which takes one primer at a time from the holder T, and transfers it to the mouth of a die, through which it is pushed into the pocket of the cartridge head. By means of the die the primers are sized and squarely and concentrically entered into the pocket. This machine inserts primers without fault, at the rate of fifty a minute.

### DESCRIPTION OF THE FRANKFORD ARSENAL MEASURING MACHINE, WITH GILL'S COUNTERPOISE BEAM FOR DIFFERENTIAL MEASUREMENT BY MECHANICAL TOUCH.

The need of an instrument for the purpose of determining dimensions by difference from verified standards has been felt in all well-regulated engineering, tool, and machine shops.

The screw, operated by a wheel with graduated periphery, has been in use for many years, and was brought to a high degree of perfection by Whiteworth, in England, and others. It may be said that, with proper safeguards in its use, it is sufficiently accurate for all practical purposes.

It is doubtful if a screw of perfectly uniform pitch throughout any considerable length can be made. The attempt to compensate for this variability of pitch is frequently made by various devices.

An interesting means of doing so is shown in the dividing engine of this arsenal. A new screw having been made with great care by Wm. Sellers & Co., of Philadelphia, it was put into the engine and was found to give, for a certain number of turns, a greater length than the nominal pitch of its thread indicated.

To counteract this an inclined plane was attached to the engine, upon which a weighted lever secured to the nut runs up or down as the nut traverses the screw in opposite directions.

The effect, as it runs up the plane, is to back the nut a small fraction of the distance it would otherwise travel, and thereby compensate for the error of the pitch, and *vice versa*. If the pitch were absolutely uniform throughout the length of the screw this would leave nothing to be desired from a mechanical point of view, but when the pitch varies from inch to inch, as is nearly always the case, instead of an inclined plane, the corrective element of the engine would have to be a surface having a series of elevations and depressions to correspond to the variations of the pitch, a result only to be attained by a "cut and try" process, alike tedious and expensive, and of only approximate accuracy. It could not be depended upon for small fractional parts of the inch, say 0.0002 inch, or more or less, such as are daily brought into use.

Short screws, or portions thereof, may be quite uniform, or so nearly so that the error can be safely disregarded, or an allowance made for it.

These considerations have led to the adoption at this arsenal of the plan of obtaining certified standards of length, diameter, &c., in suitable

forms and measuring, by difference from them, the object under examination as proposed by Mr. Richards. These standards differ by convenient fractions of an inch from one another, and by using the nearest one to the object whose dimensions are required, only a very short screw is necessary.

The machine shown in the accompanying drawing (Plate VII) is only an experimental one, but has the principal features of this system. It consists of a cast-iron bed, A, with a sliding head, B, holding one measuring point. The head may be clamped at any point desired. The spindle C carries the other measuring point. The screw inclosed in the stand A gives motion to the spindle C by means of a corresponding nut. The weight D takes up the slack of the thread to overcome lost motion. The end of the screw carries a vernier wheel, Z, divided to read 0.00001 of an inch. The rotation of this wheel moves the spindle C in and out. A scale beam, X, arranged at right angles to the line of measurement, rests on the stand K, which is movable on the frame P; at L there is a screw to regulate the contact with the fixed measuring point. One end to be beam is provided with adjustable centers RR, to hold the piece of the measured. The other end is provided with a movable weight to balance the opposite end when loaded.

Having secured the piece to be measured, the beam is balanced by the weight S. A one-grain weight is added for preponderance. The piece M is moved by the screw L against the fixed measuring point O until the beam will fall. The wheel Z is rotated to bring the spindle C with its measuring point into contact with M till the latter will just pass through the space between the points, under the influence of the preponderance of the one-grain weight. Note the vernier reading of the wheel and set the latter up 0.00001 inch. This change of distance between the points overcomes by friction the effect of the one-grain weight, and the beam remains stationery. Add two or three grains additional weight until the friction is overcome.

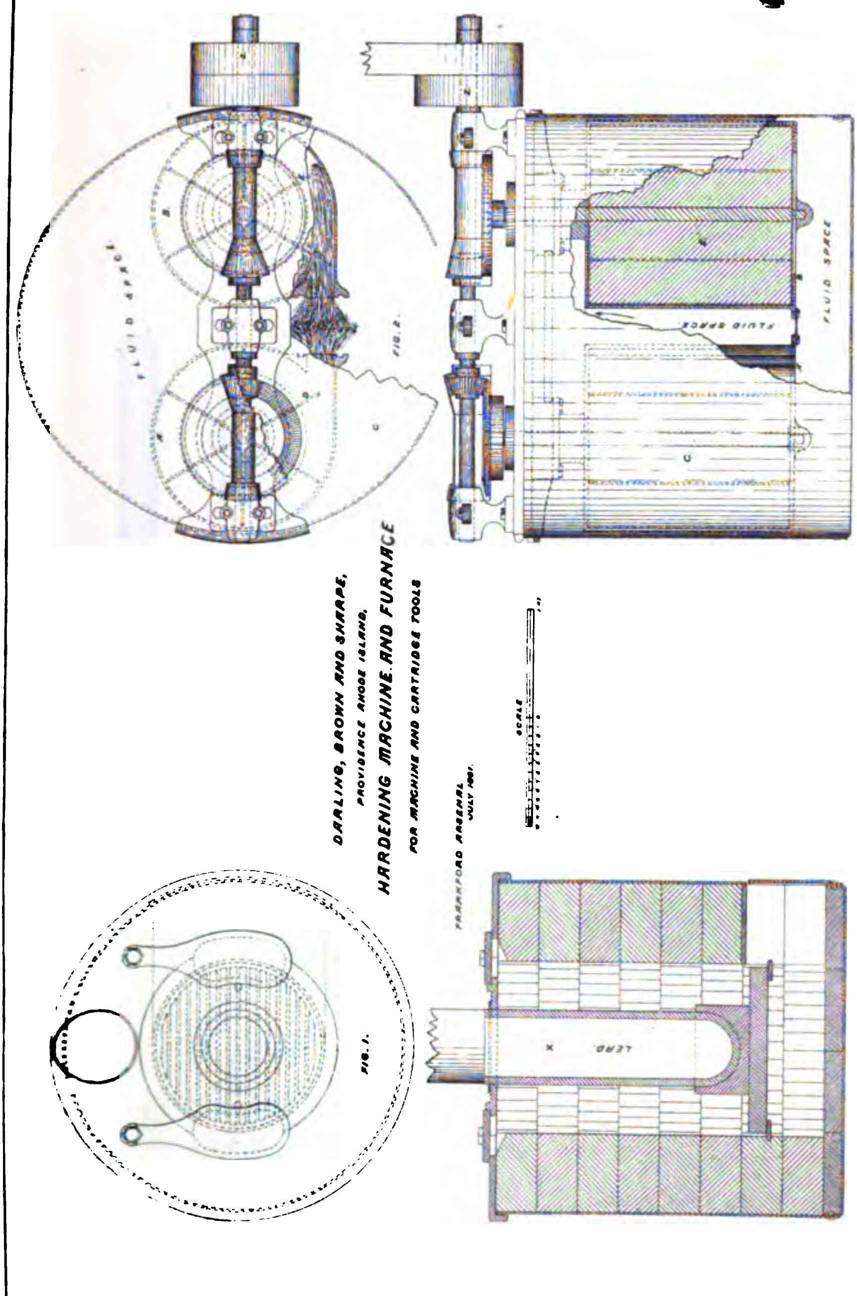
By thus measuring the standard and the piece compared with it, using equal weights for preponderance, a very close determination of dimensions is attainable.

For pieces of considerable length, a forked support, shown separately in drawing, is attached to the beam as indicated.

It is necessary that the temperature of the machine, the standard and the piece to be measured, be the same, or very nearly so. The ends of the measuring points are preferably round, instead of flat.

The personal error of holding the piece properly between the points, and that of variations in the sense of touch, as to the degree of contact with the points, are eliminated by the use of the balance and the device for holding the pieces renders handling of them unnecessary, and the consequent changes of temperature are avoided.

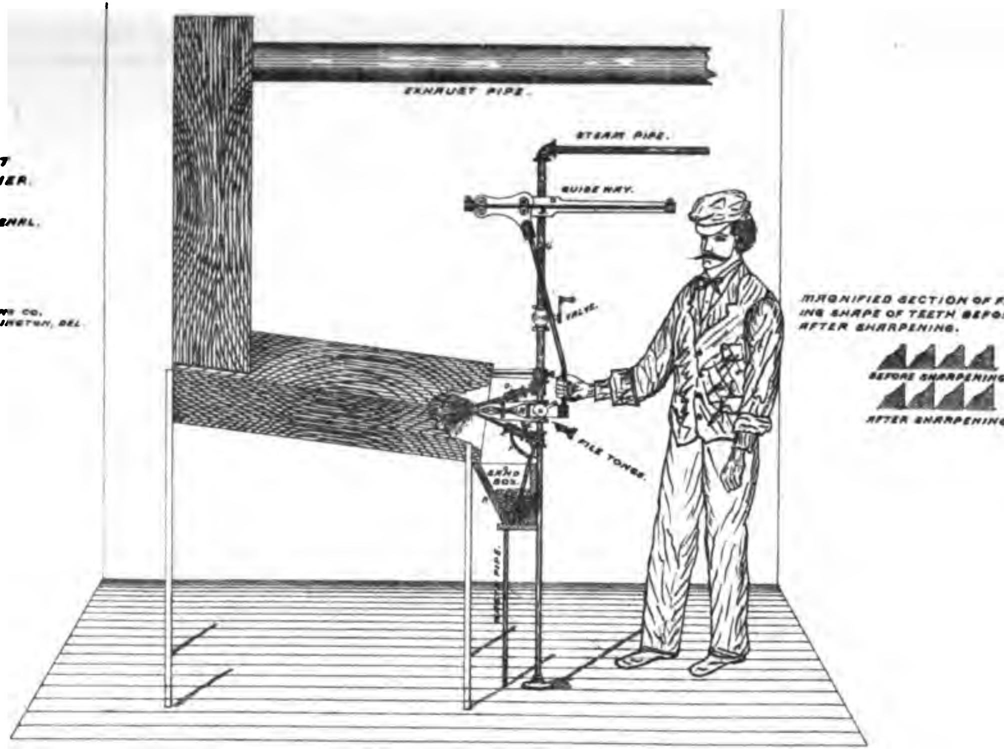
It is believed the machine will do very accurate work, and that all ordinary sources of error in its use have been provided against.

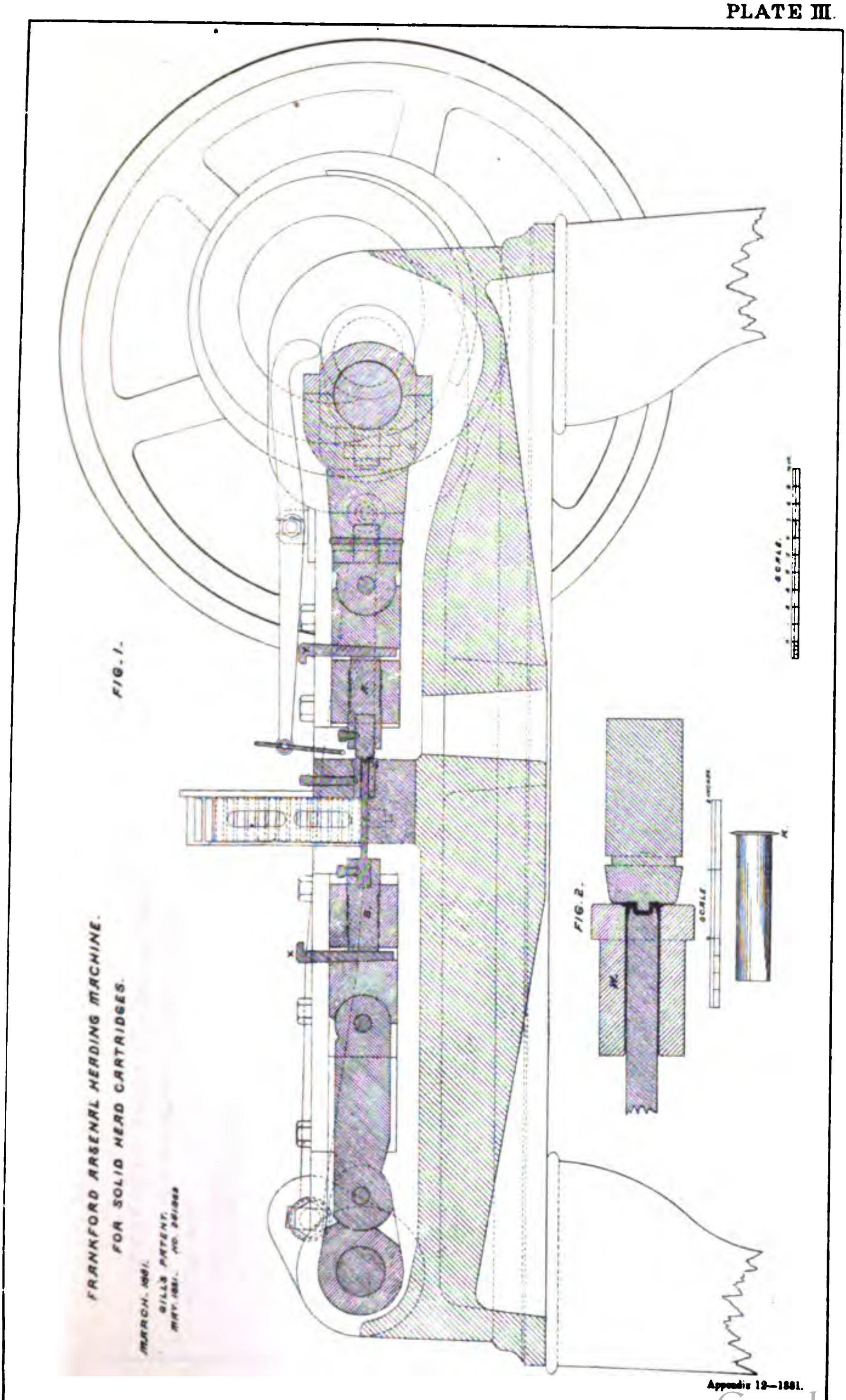

DARLING, BROWN AND SHARPE,
PROVIDENCE RHODE ISLAND,
HARDENING MACHINE AND FURNACE
FOR MACHINE AND CARTRIDGE TOOLS
FRANKFORD ARSENAL
JULY 1881.
SCALE
FLUID SPACE
FIG. 2.
FIG. 1.
LEAD

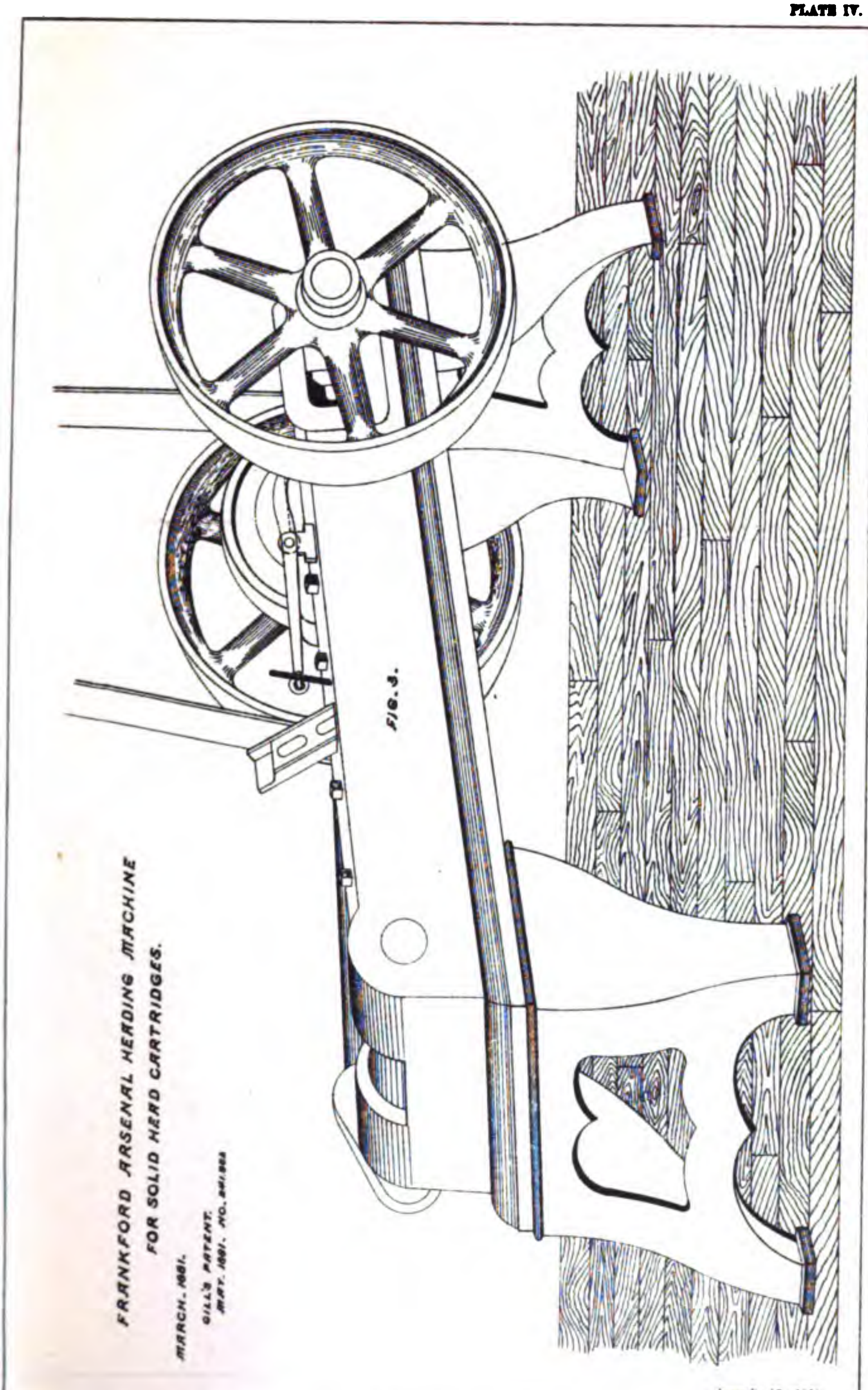
SAND BLAST
FILE SHARPENER.
IN USE AT
FRANKFORD ARSENAL.

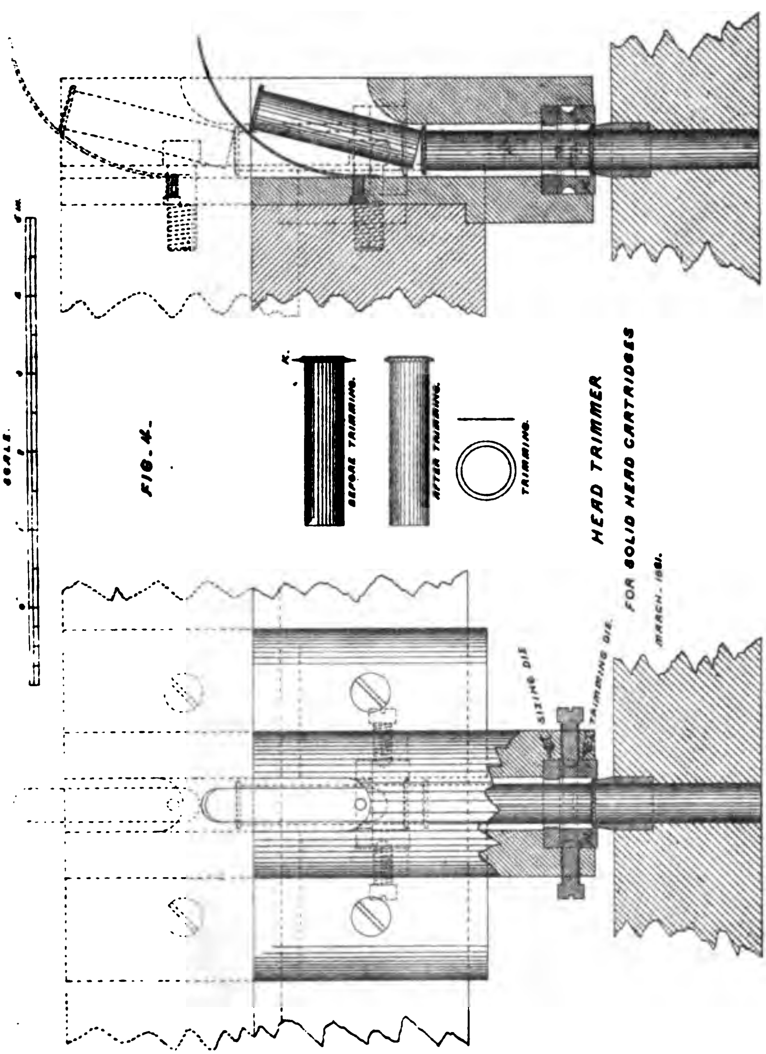
APRIL.-1881.

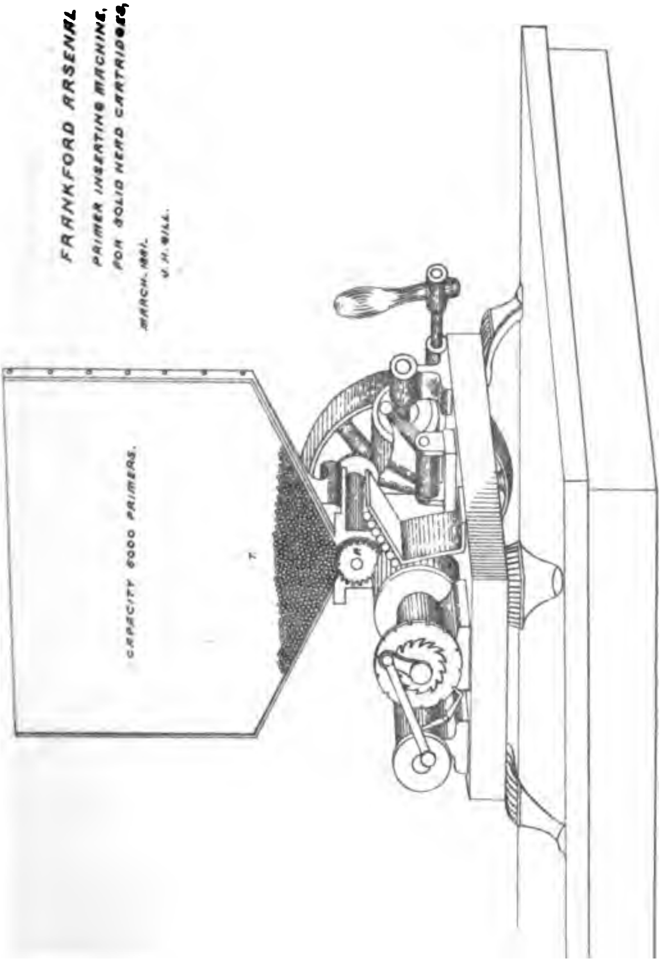
SAND BLAST FILE SHARPENING CO.
WILMINGTON, DEL.

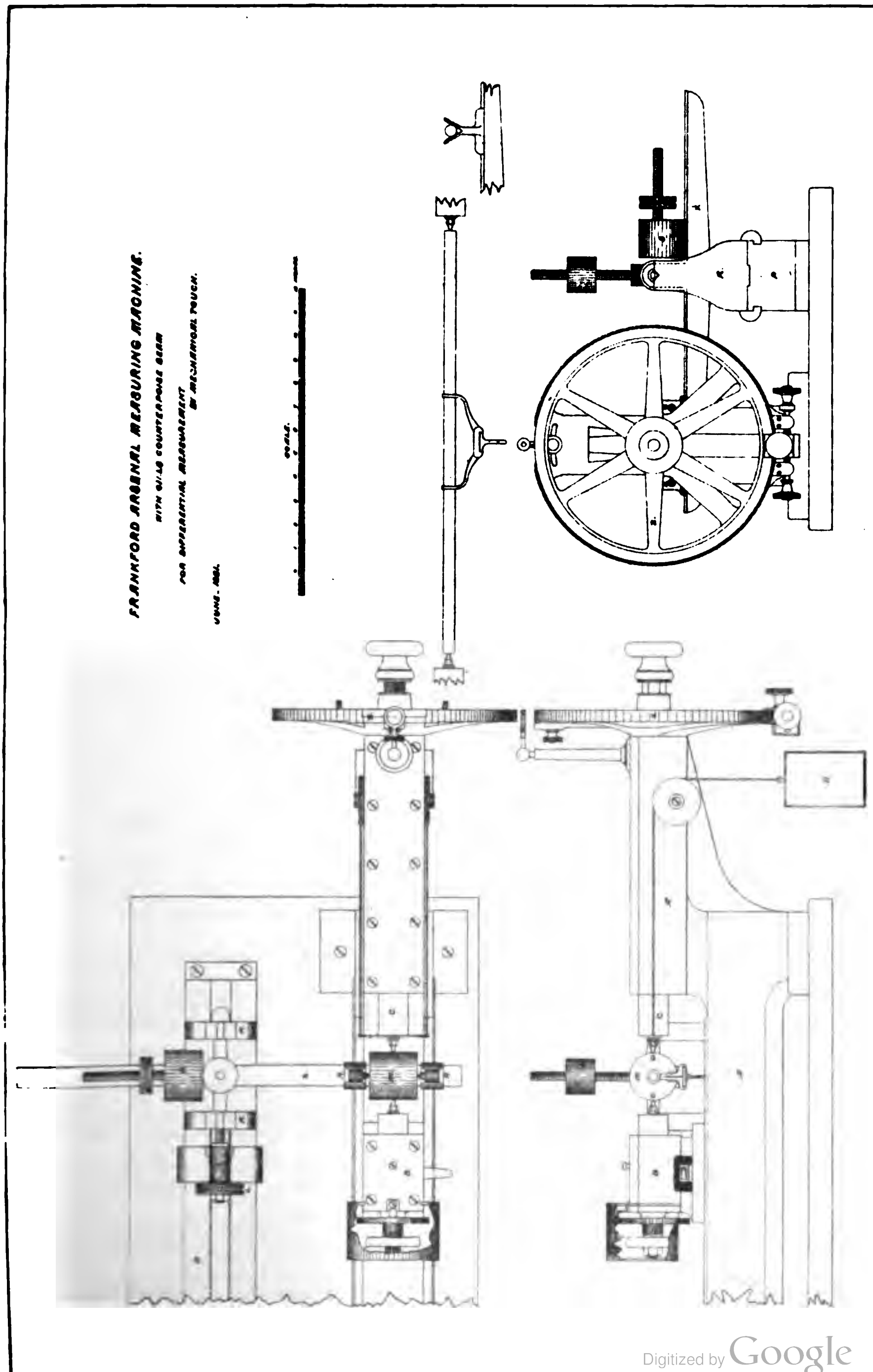



FRANKFORD ARSENAL HEADING MACHINE.
FOR SOLID HEAD CARTRIDGES.
MARCH. 1881.
GILLS PATENT.
FIG. 1.
FIG. 2.
SCALE.
SCALE.
X
Y


FRANKFORD ARSENAL HEADING MACHINE
FOR SOLID HEAD CARTRIDGES.
MARCH. 1881.
GILL'S PATENT.
MAY. 1881. NO.
FIG. 3.


SCALE.
FIG. 4.
BEFORE TRIMMING.
AFTER TRIMMING.
TRIMMING.
HEAD TRIMMER
FOR SOLID HEAD CARTRIDGES
MARCH. 1881.
SIZING DIE
TRIMMING DIE.


FRANKFORD ARSENAL
PRIMER INSERTING MACHINE,
FOR SOLID HEAD CARTRIDGES,
MARCH, 1881.
J. H. BILL.
CAPACITY 5000 PRIMERS.


FRANKFORD ARSENAL MEASURING MACHINE.
WITH COUNTERPOISE BEAM
FOR DIFFERENTIAL MEASUREMENT
BY MECHANICAL TOUCH.
JUNE.
SCALE.

## APPENDIX 13.

### EXPERIMENTS WITH SMALL-ARMS HAVING VARYING LENGTH AND WEIGHT OF BARRELS AND CHARGES OF POWDER AND BULLETS, BY CAPT. JOHN E. GREER, UNDER THE DIRECTION OF COL. JAMES G. BENTON, COMMANDING THE NATIONAL ARMORY.

JUNE 16, 1881.

SIR: I have the honor to submit herewith results of trials at this armory of Springfield rifles, having barrels of different lengths and weights; sights of various patterns, such as Springfield and Sharps' peep and globe, and ordinary service, and cartridges with powder charges, varying from 70 to 90 grains, and bullets from 405 to 550 grains.

In all, 13 different Springfield rifles were tried, 2 of them having special breech systems fitted to them, 1 the Hotchkiss and the other the Sharps.

In addition, a Sharps' long range was fired a very limited number of times only, with a patched bullet, its chamber not being adapted to the use of the bullets prepared at this armory and the Frankford Arsenal; which are of an essentially military character.

Data concerning the rifles and ammunition used are given in the following table:

| Rifle. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Kind. | Barrels. | | | | Rifling. | | Stock. | Sights. |
| | Length. | Weight. | | Form. | Twist. | No. of grooves. | | |
| | | Lbs. | oz. | | Inches. | | | |
| No. 1. Springfield, special .... | 2[illegible]75 | 5 | 1.5 | Cylinder ......... | 19⅝ | 6 | Short. | Peep and globe, Sharps'. |
| No. 2. Springfield, special .... | 32.7 | 5 | 1 | Frustum of a cone | 19⅝ | 6 | ..do .. | Do. |
| No. 3. Springfield, special .... | 32.7 | 4 | 2 | ....do ........... | 19⅝ | 6 | ..do .. | Do. |
| No. 4. Springfield, special .... | 32.15 | 6 | 5.5 | Octagonal ........ | 22 | 3 | ..do .. | Peep and globe, Springfield. |
| No. 5. Springfield, long-range. | 32.6 | 3 | 9.6 | Service .......... | 19⅝ | 6 | Full.. | Peep and globe, Bull's. |
| No. 6. Springfield, long-range | 32.6 | 3 | 9.6 | ....do ........... | 19⅝ | 6 | ..do .. | Peep and globe, Sharps'. |
| No. 7. Springfield, long-range | 32.6 | 3 | 9.6 | ....do ........... | 19⅝ | 6 | ..do .. | Service. |
| No. 8. Service, long-chamber | 32.6 | 3 | 9.6 | ....do ........... | 22 | 3 | ..do .. | Peep and globe, Sharps'. |
| No. 9. Service, long-chamber . | 32.6 | 3 | 9.6 | ....do ........... | 22 | 3 | ..do .. | Service. |
| No. 10. Service ................ | 32.6 | 3 | 9.6 | ....do ........... | 22 | 3 | ..do .. | Peep and globe, Sharps'. |
| No. 11. Service ........... ..... | 32.6 | 3 | 9.6 | ....do ........... | 22 | 3 | ..do .. | Service. |
| No. 12. Springfield, special, Hotchkiss system ........... | 31.55 | 4 | 15.5 | Frustum of a cone | 18.5* | 6 | Short. | Peep and globe, Bull's. |
| No. 13. Springfield, special, Sharps' system .............. | 25.87 | 5 | 5.5 | Cylindrical ....... | 18.5* | 6 | ..do .. | Peep and globe, Sharps'. |

| Rifle. | | | | Cartridge. | | | |
|---|---|---|---|---|---|---|---|
| Kind. | Ramrod. | Total length of arm. | Total weight of arm. | Weight of powder. | Weight of bullet. | Shell. | Remarks. |
| | | *Inches.* | *Lbs.oz.* | *Grs.* | *Grs.* | | |
| No. 1. Springfield, special | None | 45.07 | 9 14 | 80 | 500 | Frankford Arsenal, copper, solid head reloading. | |
| No. 2. Springfield, special | do | 52.02 | 10 1/8 | 80 | 500 | | No tip or grip. |
| No. 3. Springfield, special | do | 52.02 | 9 1 | 80 | 500 | | Do. |
| No. 4. Springfield, special | do | 51.45 | 9 15 | 80 | 500 | | Do. |
| No. 5. Springfield, long-range. | Full length | 51.92 | 9 4 | 80 | 500 | | Do. |
| No. 6. Springfield, long-range. | do | 51.92 | 9 4 1/2 | 80 | 500 | | Hotchkiss butt plate. |
| No. 7. Springfield, long-range. | do | 51.92 | 8 15 | 80 | 500 | | Do. |
| No. 8. Service, long-chamber | do | 51.92 | 9 3 1/2 | 80 | 500 | | Do. |
| No. 9. Service, long-chamber | do | 51.92 | 8 12 | 80 | 500 | | |
| No. 10. Service | do | 51.92 | 9 6 | 70 | 500 | | |
| No. 11. Service | do | 51.92 | 8 15 | 70 | 500 | | |
| No. 12. Springfield, special, | | | | | 500 | | |
| Hotchkiss system | None | 51.5 | 10 7 | 80 | 500 | | Hotchkiss butt plate; no tip. |
| No. 13. Springfield, special, | | | | | | | |
| Sharps' system | do | 42.7 | 10 4 | 80 | 500 | | No tip. |

* Grooves and lands of equal width.

The chief object of the trials was to determine whether increased accuracy could be obtained by increasing the weight of the barrel over that of the service, special reference being had to the construction of a "marksmen's rifle."

A very moderate amount of firing quickly demonstrated that if exceedingly heavy barrels possessed any superiority in this respect, it must be with correspondingly heavy charges; that for the cartridge issued for trial in the field having 70 grains of powder and 500 grains bullet, or even with the 80 grains charge, and same bullet as prepared at the Frankford Arsenal and used at Creedmoor last fall, no great increase in weight of barrel was either necessary or desirable. There was, however, a question as to the propriety of slightly stiffening the service barrel by making it a straight taper, leaving the diameters at breech and muzzle the same as at present, and filling in between them, thereby adding nearly 9 ounces to the weight; this not so much for the purpose of increasing the accuracy of fire as to enable the barrel to better endure the rough usage of the service. One barrel, No. 3, prepared in this manner has given excellent results with the 80 grains charge. It is worthy of observation that the 70 grains cartridge has worked very satisfactorily in the long chambered guns, all except Nos. 10 and 11 being adopted for the 80 grains shell.

Another fact brought out by this firing was the slight value to a skilled marksman of peep and globe over open sights.

The peep and globe or aperture sights devised by Mr. F. R. Bull, of this armory, appear to have given the most perfect satisfaction to the men using them, and are greatly to be preferred to all others, if such sights are to be issued. The peep-sight has a lateral as well as vertical motion, by means of which adjusting at the muzzle of a loaded gun is avoided. The front sight is stationary and attached to the stud of the service sight. Both front and rear sights may be quickly removed if desired, leaving the service sights ready for use.

On examination of the accompanying tables it will be seen that very

little difference in accuracy was observed with barrels from 25.75 to 32.7 inches in length.

Another circumstance of even more importance, constantly made manifest during the last year, is that for an unpatched bullet like the service the 6-grooved rifling has no superiority over the 3-grooved, while the latter is more easily made and cleaned. In support of this statement reference is had not only to this but previous reports on this subject. In addition, there are now submitted sheets showing the accuracy obtained at 200, 400, 600, 800, and 1,000 yards, while firing for drift with four unselected service barrels, two having a right and two a left hand twist, one of each being fitted to Springfield and the others to Hotchkiss breech-systems; the powder charge being 70 grains.

It may be further said that these latter results represent very nearly the average of a large number at the same ranges with the same cartridge.

In this connection attention is invited to the performance of rifles Nos. 10 and 11 with four varieties of the 70 grains cartridge and 500 grains bullet, as shown in the latter part of the 500 yards summary. This remarkable showing it is not supposed is due entirely to the rifling, greater variations being produced by the cartridge than by the gun, but is due to the system as a whole.

From the foregoing it seems probable that the straight-tapered service barrel, or one of equal weight shortened a few inches if preferred, rifled with the service twist and groove, short stocked as in the trial, and sighted with Bull's peep and globe in addition to the service sights, will make a suitable combination for a special rifle, while the weight of the whole will not exceed 9¼ to 9½ pounds. Unless the 80 grains cartridge is to be issued, this rifle should be chambered for the service shell.

Very respectfully, your obedient servant,

JOHN E. GREER,
*Captain of Ordnance, U. S. A.*

To the COMMANDING OFFICER,
*National Armory.*

NOTE.—Owing to a lack of ammunition, the delay incident to the preparation of rifles Nos. 12 and 13, the issuing of the Sharps sights, and to other work, the firing was discontinued March 23, and summaries of results made out. For trials at 800 yards since that date an auxiliary summary is submitted.

*Summary of result of firing at 500 yards.*

| Rifle. | Sight. | Powder. | | Bullet. | | | No. of target. | M. A. deviation. | | | | Average. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Flat point. | | Round point. | | |
| | | Weight. | Kind. | Weight. | Caliber. | Kind. | | $\frac{1}{12}$ tin. | $\frac{1}{17}$ tin. | $\frac{1}{12}$ tin. | $\frac{1}{17}$ tin. | |
| | | *Grs.* | | *Grs.* | | | | | | | | |
| No. 1. Springfield; special | Peep and globe; Sharps' | 80 | Unknown | 500 | .4555 | Frankford | 1 | | | | 5.2 | 6.2 |
| | | | | | | | 2 | | | | 6.7 | |
| | | | | | | | 3 | | | | 6.7 | |
| No. 2. Springfield; special | do | 80 | do | 500 | .4555 | do | 1 | | | | 7.6 | 8. |
| | | | | | | | 2 | | | | 7.6 | |
| | | | | | | | 3 | | | | 8.7 | |
| No. 3. Springfield; special | do | 80 | do | 500 | .4555 | do | 1 | | | | 7.6 | 7.1 |
| | | | | | | | 2 | | | | 6.7 | |
| No. 4. Springfield; special | Peep and globe; Springfield | 80 | do | 500 | .4555 | do | 1 | | | | 5.0 | 4.9 |
| | | | | | | | 2 | | | | 4.8 | |
| No. 5. Springfield; long-range | Peep and globe; Bulls' | 80 | do | 500 | .4555 | do | 1 | | | | 11.0 | 8.7 |
| | | | | | | | 2 | | | | 4.3 | |
| | | | | | | | 3 | | | | 8.0 | |
| | | | | | | | 4 | | | | 11.6 | |
| No. 6. Springfield; long-range | Peep and globe; Sharps' | 80 | do | 500 | .4555 | do | 1 | | | | 6.0 | 7.3 |
| | | | | | | | 2 | | | | 8.7 | |
| | | | | | | | 3 | | | | 5.2 | |
| | | | | | | | 4 | | | | 8.9 | |
| | | | | | | | 5 | | | | 8.0 | |
| | | | | | | | 6 | | | | 8.4 | |
| | | | | | | | 7 | | | | 6.5 | |
| | | | | | | | 8 | | | | 7.9 | |
| | | | | | | | 9 | | | | 5.8 | |
| No. 7. Springfield; long-range | Open service | 80 | do | 500 | .4555 | do | 1 | | | | 7.6 | 7.7 |
| | | | | | | | 2 | | | | 6.4 | |
| | | | | | | | 3 | | | | 6.6 | |
| | | | | | | | 4 | | | | 9.9 | |
| | | | | | | | 5 | | | | 7.4 | |
| | | | | | | | 6 | | | | 9.0 | |
| | | | | | | | 7 | | | | 7.6 | |
| | | | | | | | 8 | | | | 5.9 | |
| | | | | | | | 9 | | | | 8.9 | |
| No. 8. Service; long-chamber | Peep and globe; Sharps' | 80 | do | 500 | .4555 | do | 1 | | | | 9.5 | 10.1 |
| | | | | | | | 2 | | | | 10.8 | |
| No. 9. Service; long-chamber | Open service | 80 | do | 500 | .4555 | do | 1 | | | | 14.9 | 10.3 |
| | | | | | | | 2 | | | | 7.8 | |
| | | | | | | | 3 | | | | 8.1 | |
| No. 10. Service | Peep and globe; Sharps' | 70 | do | 500 | .4565 | do | 1 | | | | 8.1 | 8.1 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 11. Service | Open service | 70 | ....do | 500 | .4555 | ....do | 1 | ...... | ...... | ...... | 8.3 | 8.3 |
| No. 10. Service | Peep and globe; Sharps' | 70 | ....do | 500 | .4555 | ....do | 1 | 6.0 | 5.9 | 4.3 | 6.1 | 5.7 |
| | | | | | | | 2 | 5.7 | 4.8 | 6.4 | 5.0 | |
| | | | | | | | 3 | 5.5 | 6.6 | 4.4 | 7.6 | |
| | | | | | | | 4 | 5.8 | 7.2 | 5.8 | 8.4 | |
| | | | | | | | 5 | 5.6 | 5.4 | 5.8 | 5.4 | |
| | | | | | | | 6 | ...... | 6.5 | ...... | 6.9 | |
| No. 11. Service | Open service | 70 | ....do | 500 | .4555 | ....do | 1 | 6.4 | 6.0 | 6.1 | 5.6 | 6.5 |
| | | | | | | | 2 | 5.1 | 5.8 | 6.0 | 8.8 | |
| | | | | | | | 3 | 6.6 | 5.2 | 6.2 | 7.3 | |
| | | | | | | | 4 | 5.1 | 6.6 | 6.9 | 8.4 | |
| | | | | | | | 5 | 6.6 | 6.1 | 6.4 | 8.7 | |
| | | | | | | | 6 | ...... | 4.5 | ...... | 7.7 | |
| *No. 5. Springfield; long-range | Peep and globe: Bull's | 80 | Hazard service musket. | 500 | .4555 | Springfield | 1 | ...... | ...... | ...... | 9.0 | ...... |
| *No. 6. Springfield; long-range | Peep and globe; Sharps' | 80 | ....do | 500 | .4555 | ....do | 1 | ...... | ...... | ...... | 7.3 | ...... |
| *No. 7. Springfield; long-range | Open service | 80 | ....do | 500 | .4555 | ....do | 1 | ...... | ...... | ...... | 9.7 | ...... |
| *No. 8. Service; long-chamber | Peep and globe; Sharps' | 80 | ....do | 500 | .4555 | ....do | 1 | ...... | ...... | ...... | 5.1 | ...... |

*Bullet, $\frac{1}{16}$ tin.

*Summary of results of firing at 800 yards.**

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | M. A. deviations. Flat point. $\frac{1}{12}$ tin. | M. A. deviations. Flat point. $\frac{1}{17}$ tin. | M. A. deviations. Round point. $\frac{1}{12}$ tin. | M. A. deviations. Round point. $\frac{1}{17}$ tin. | Average. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | | | | | |
| No. 1. Springfield, special | Peep and globe; Sharps' | 80 | Unknown | 500 | .4555 | Frankford | 1 | | | | 16.8 | 15.5 |
| | | | | | | | 2 | | | | 19.8 | |
| | | | | | | | 3 | | | | 9.8 | |
| No. 2. Springfield, special | do | 80 | do | 500 | .4555 | do | 1 | | | | 15.7 | 14.4 |
| | | | | | | | 2 | | | | 14.3 | |
| | | | | | | | 3 | | | | 13.3 | |
| No. 3. Springfield, special | do | 80 | do | 500 | .4555 | do | 1 | | | | 12.5 | 14.3 |
| | | | | | | | 2 | | | | 17.0 | |
| | | | | | | | 3 | | | | 13.5 | |
| No. 4. Springfield, special | Peep and globe; Springfield | 80 | do | 500 | .4555 | do | 1 | | | | 16.3 | 16.6 |
| | | | | | | | 2 | | | | 20.0 | |
| | | | | | | | 3 | | | | 13.4 | |
| No. 5. Springfield, long-range | Peep and globe; Bull's | 80 | do | 500 | .4555 | do | 1 | | | | 22.7 | 17.4 |
| | | | | | | | 2 | | | | 11.5 | |
| | | | | | | | 3 | | | | 18.0 | |
| No. 6. Springfield, long-range | Peep and globe; Sharps' | 80 | do | 500 | .4555 | do | 1 | | | | 21.5 | 18.7 |
| | | | | | | | 2 | | | | 22.0 | |
| | | | | | | | 3 | | | | 21.2 | |
| | | | | | | | 4 | | | | 10.1 | |
| No. 7. Springfield, long-range | Open service | 80 | do | 500 | .4555 | do | 1 | | | | 12.4 | 12.7 |
| | | | | | | | 2 | | | | 12.7 | |
| | | | | | | | 3 | | | | 13.3 | |
| | | | | | | | 4 | | | | 12.5 | |
| No. 8. Service, long-chamber | Peep and globe; Sharps' | 80 | do | 500 | .4555 | do | 1 | | | | 16.5 | 20.7 |
| | | | | | | | 2 | | | | 26.6 | |
| | | | | | | | 3 | | | | 19.0 | |
| No. 9. Service, long-chamber | Open service | 80 | do | 500 | .4555 | do | 1 | | | | 26.6 | 20.6 |
| | | | | | | | 2 | | | | 17.5 | |
| | | | | | | | 3 | | | | 17.6 | |
| No. 10. Service | Peep and globe; Sharps' | 70 | do | 500 | .4555 | do | 1 | | | | 18.3 | 13.8 |
| | | | | | | | 2 | | | | 13.5 | |
| | | | | | | | 3 | | | | 9.5 | |
| No. 11. Service | Open service | 70 | do | 500 | .4555 | do | 1 | | | | 25.1 | 17.7 |
| | | | | | | | 2 | | | | 15.3 | |
| | | | | | | | 3 | | | | 12.7 | |
| No. 1. Springfield, special | Peep and globe; Sharps' | 70 | do | 500 | .4555 | do | 1 | 17.1 | 10.9 | 20.3 | 14.5 | 15.7 |
| No. 2. Springfield, special | do | 70 | do | 500 | .4535 | do | 1 | 14.3 | 11.5 | 14.2 | 18.3 | 14.6 |
| No. 3. Springfield, special | do | 70 | do | 500 | .4555 | do | 1 | 16.0 | 13.6 | 13.3 | 15.1 | 14.5 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 4. Springfield, special | Peep and globe; Springfield | 70 | ...do | 500 | .4555 | ...do | 1 | 12.5 | 14.5 | 11.7 | 18.8 | 14.4 |
| No. 5. Springfield, long-range | Peep and globe; Bull's | 70 | ...do | 500 | .4555 | ...do | 1 | 12.1 | 14.6 | 10.6 | 12.3 | 15.1 |
| | | | | | | | 2 | 19.9 | 17.0 | 17.6 | 17.0 | |
| No. 6. Springfield, long-range | Peep and globe; Sharps' | 70 | ...do | 500 | .4555 | ...do | 1 | 14.7 | 17.8 | 20.6 | 19.2 | 19.1 |
| | | | | | | | 2 | 23.0 | 22.9 | 10.8 | 13.7 | |
| No. 7. Springfield, long-range | Open service | 70 | ...do | 500 | .4555 | ...do | 1 | 17.8 | 11.6 | 17.8 | 19.2 | 18.3 |
| | | | | | | | 2 | 23.2 | 17.5 | 15.8 | 23.6 | |
| No. 8. Service, long-chamber | Peep and globe; Sharps' | 70 | ...do | 500 | .4555 | ...do | 1 | 16.3 | 19.4 | 20.1 | 17.5 | 18.6 |
| No. 9. Service, long-chamber | Open service | 70 | ...do | 500 | .4555 | ...do | 1 | 15.5 | 13.2 | 16.5 | 19.9 | 16.3 |
| No. 10. Service | Peep and globe; Sharps' | 70 | ...do | 500 | .4555 | ...do | 1 | 15.2 | 21.7 | 12.6 | 16.1 | 16.1 |
| | | | | | | | 2 | 15.0 | 14.5 | 14.3 | 17.5 | |
| | | | | | | | 3 | ........ | ........ | 17.4 | 16.3 | |
| No. 11. Service | Open service | 70 | ...do | 500 | .4555 | ...do | 1 | 20.7 | 15.2 | 17.6 | 18.8 | 18.1 |
| | | | | | | | 2 | 14.9 | 16.9 | 23.3 | 17.0 | |
| | | | | | | | 3 | ........ | ........ | 13.5 | 23.7 | |

* Up to March 23, 1881.

*Auxiliary summary,* 800 yards.*

| Rifle. | Sights. | Powder: Weight. | Powder: Kind. | Bullet: Weight. | Bullet: Caliber. | Bullet: Kind. | No. of targets. | M. A. deviations. | Average. |
|---|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | | |
| No. 1. Springfield, special. | Peep and globe; Sharps'. | 80 | Unknown. | 500 | .4555 | Frankford. | 1<br>2 | 10.7<br>14.8 | 12.7 |
| No. 2. Springfield, special. | ....do .......... | 80 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2 | 13.5<br>12.2 | 12.8 |
| No. 3. Springfield, special. | ....do .......... | 80 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2<br>3<br>4<br>5 | 12.0<br>10.5<br>14.9<br>18.7<br>14.4 | 14.1 |
| No. 4. Springfield, special. | Peep and globe; Springfield. | 80 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2 | 21.9<br>9.7 | 15.2 |
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 80 | ....do .... | 500 | .4555 | ...do ...... | 1 | 11.7 | 11.7 |
| No. 8. Service, long-chamber. | Peep and globe; Sharps'. | 80 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2 | 9.9<br>16.4 | 13.1 |
| No. 12. Springfield, special, Hotchkiss system, long-chambered. | Peep and globe; Bull's. | 80 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10<br>11 | 13.8<br>12.5<br>14.7<br>17.7<br>17.7<br>11.5<br>21.1<br>12.7<br>18.6<br>14.6<br>16.5 | 15.6 |
| No. 13. Springfield, special, Sharps' system, long-chambered. | Peep and globe; Sharps'. | 80 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2<br>3 | 16.8<br>18.6<br>16.1 | 15.5 |
| No. 1. Springfield, special. | ....do .......... | 70 | ....do ..... | 500 | .4555 | .. do ...... | 1<br>2 | 17.9<br>14.1 | 16.0 |
| No. 2. Springfield, special. | ....do .......... | 70 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2 | 13.7<br>21.3 | 17.5 |
| No. 3. Springfield, special. | ....do .......... | 70 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2 | 22.7<br>21.8 | 22.2 |
| No. 4. Springfield, special. | Peep and globe; Springfield. | 70 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2 | 23.9<br>20.7 | 22.3 |
| No. 8. Service long-chamber. | Peep and globe; Sharps'. | 70 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2 | 23.2<br>26.7 | 24.9 |
| No. 11. Service ....... | Service......... | 70 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2<br>3<br>4 | 20.0<br>22.2<br>13.5<br>18.0 | 18.4 |
| No. 12. Springfield, special, Hotchkiss system, long-chamber. | Peep and globe; Bull's. | 70 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2<br>3<br>4<br>5<br>6<br>7 | 23.1<br>19.4<br>13.9<br>19.4<br>23.4<br>27.3<br>16.2 | 20.4 |
| No. 13. Springfield, special, Sharps' system, long-chamber. | Peep and globe; Sharps'. | 70 | ....do ..... | 500 | .4555 | ...do ...... | 1<br>2 | 20.5<br>19.6 | 20.0 |
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 80 | Hazard service musket. | 550 | .4555 | Springfield.. | 1 | 23.7 | 23.7 |
| No. 5, Springfield, long-range. | ....do .......... | 90 | ....do ..... | 550 | .4555 | ...do ...... | 1<br>2<br>3<br>4 | 13.7<br>16.0<br>12.7<br>14.6 | 14.2 |
| No. 12. Springfield, special, Hotchkiss system, long-chambered. | ....do .......... | 80 | ....do ..... | 550 | .4555 | ...do ...... | 1<br>2 | 13.2<br>22.1 | 17.6 |
| No. 12. Springfield, special, Hotchkiss system, long-chambered. | ....do .......... | 90 | ....do ..... | 550 | .4555 | ...do ...... | 1<br>2<br>3<br>4 | 10.8<br>21.7<br>24.5<br>24.1 | 20.3 |
| No. 13. Sharp's long-range.† | Peep and globe; Sharps'. | 100 | ....do .... | 550 | ...... | Patched .. | 1<br>2<br>3 | 11.2<br>7.1<br>14.4 | 10.9 |

* April 27 to June 13, inclusive.

† Weight of barrel, 6 pounds 3 ounces.

*Summary of firing at* 200, 400, 600, 800, *and* 1,000 *yards.*

[Service rifling.]

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Mean deviations. 200 yards. | 400 yards. | 600 yards. | 800 yards. | 1,000 yards. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grs | | Grs. | | | | | | | | |
| Service | 70 | Dupont | 500 | .4555 | Springfield | 8 | 2.8 | | | | |
| Do | 70 | ...do | 500 | .4555 | ...do | 8 | | 6.26 | | | |
| Do | 70 | ...do | 500 | .4555 | ...do | 8 | | | 8.2 | | |
| Do | 70 | ...do | 500 | .4555 | ...do | 8 | | | | 11.5 | |
| Do | 70 | ...do | 500 | .4555 | ...do | 6 | | | | | 21.6 |

500 *yards range.—March* 5, 1881.

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | M. V. | M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Grs | | Grs | | | | | | |
| No. 7. Springfield, long-range, 6 grooves, 19⅛ twist. | Service | 80 | Hazard, F. G. | 500 | .455 | Frankford, $\frac{1}{17}$ tin. | 1 | 4.9 | 4.1 | 6.4 |
| Do | ...do | 80 | ...do | 500 | .455 | ...do | 2 | 3.4 | 6.8 | 7.6 |
| Do | ...do | 80 | ...do | 500 | .455 | ...do | 3 | 5.1 | 4.2 | 6.6 |
| Do | ...do | 80 | ...do | 500 | .455 | ...do | 4 | 4 | 4.4 | 5.9 |
| | | | | | | | Mean | 4.3 | 4.8 | 6.6 |
| No. 6. Springfield, long-range, 6 grooves, 19⅛ twist. | Peep and globe; Sharps'. | 80 | ...do | 500 | .455 | ...do | 1 | 5.7 | 6.6 | 8.7 |
| Do | ...do | 80 | ...do | 500 | .455 | ...do | 2 | 3.2 | 5.6 | 6.5 |
| Do | ...do | 80 | ...do | 500 | .455 | ...do | 3 | 2.3 | 4.6 | 5.2 |
| Do | ...do | 80 | ...do | 500 | .455 | ...do | 4 | 6.4 | 4.6 | 7.9 |
| | | | | | | | Mean | 4.4 | 5.3 | 7.1 |

500 *yards range.—March* 9, 1881.

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | M. H. | M. V. | M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| No. 1. Springfield, special. | Peep and globe; Sharps'. | 80 | ...do | 500 | .455 | ...do | 1 | 3.4 | 3.9 | 5.2 |
| No. 2. Springfield, special. | ...do | 80 | ...do | 500 | .455 | ...do | 1 | 5.3 | 5.5 | 7.6 |
| No. 3 Springfield, special. | ...do | 80 | ...do | 500 | .455 | ...do | 1 | 6.8 | 3.4 | 7.6 |
| No. 4. Springfield, special. | Peep and globe; Springfield. | 80 | ...do | 500 | .455 | ...do | 1 | 3. | 4. | 5. |
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 80 | ...do | 500 | .455 | ...do | 1 | 6.7 | 8.7 | 11 |
| No. 6. Springfield, long-range. | Peep and globe; Sharps'. | 80 | ...do | 500 | .455 | ...do | 1 | 4.2 | 4.2 | 6 |
| Do | ...do | 80 | ...do | 500 | .455 | ...do | 2 | 4.4 | 7.2 | 8.4 |
| | | | | | | | Mean | 4.3 | 5.7 | 7.2 |
| No. 7. Springfield, long-range. | Service | 80 | ...do | 500 | .455 | ...do | 1 | 6 | 4.6 | 7.6 |
| Do | ...do | 80 | ...do | 500 | .455 | ...do | 2 | 6.9 | 5.8 | 9. |
| | | | | | | | Mean | 6.4 | 5.2 | 8.3 |

500 *yards range—March* 9, 1881—Continued.

| Rifle. | Sight. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Weight. | Kind. | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| | | *Grs.* | | *Grs.* | | | | | | |
| No. 8. Service, long-chamber. | Peep and globe; Sharps'. | 80 | Hazard, F. G. . | 500 | .455 | Franford, $\frac{1}{17}$ tin. | 1 | 7.4 | 6 | 9.5 |
| No. 9. Service; long.chamber. | Service........ | 80 | ....do ........ | 500 | .455 | ....do .......... | 1 | 10.6 | 10.5 | 14.9 |
| Do........ | ....do ......... | 80 | ....do ........ | 500 | .455 | ....do .......... | 2 | 5.7 | 5.8 | 7.8 |
| | | | | | | | Mean | 8.1 | 7.9 | 11.3 |
| No. 10. Service. | Peep and globe; Sharp's. | 70 | ....do ........ | 500 | .455 | ....do .......... | 1 | 7. | 4. | 8.1 |
| No. 11. Service. | Service ....... | 70 | ....do ........ | 500 | .455 | ....do .......... | 1 | 4.3 | 7.1 | 8.6 |

500 *yards range.—March* 14, 1881.

[Strong breeze from the left and rear.]

| Rifle. | Sight. | Powder weight. | Powder kind. | Bullet weight. | Caliber. | Bullet kind. | No. of targets. | M. H. | M. V. | M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| No. 1. Springfield, special. | Peep and globe; Sharps'. | 80 | Unknown..... | 500 | .455 | ....do .......... | 1 | 4.6 | 4.9 | 6.7 |
| Do........ | ....do ......... | 80 | ....do ........ | 500 | .455 | ....do .......... | 2 | 2.1 | 6.3 | 6.7 |
| | | | | | | | Mean | 3.3 | 5.6 | 6.7 |
| No. 2. Springfield, special. | ....do ......... | 80 | ....do ........ | 500 | .455 | ....do .......... | 1 | 5.2 | 5.5 | 7.6 |
| Do........ | ....do ......... | 80 | ....do ........ | 500 | .455 | ....do .......... | 2 | 7.2 | 4.8 | 8.7 |
| | | | | | | | Mean | 6.2 | 5.1 | 8.1 |
| No. 3. Springfield, special. | ....do ......... | 80 | ....do ........ | 500 | .455 | ... do .......... | 1 | 5 | 4.5 | 6.7 |
| No. 4. Springfield, special. | Peep and globe; Springfield. | 80 | ....do ........ | 500 | .455 | ....do .......... | 1 | 3.7 | 2.9 | 4.7 |
| No. 5. Springfield; long-range. | Peep and globe; Bull's. | 80 | ....do ........ | 500 | .455 | ....do .......... | 1 | 2.4 | 3.6 | 4.3 |
| Do........ | ....do ......... | 80 | Hazard musket | 500 | .4555 | Springfield, $\frac{1}{18}$ tin | 1 | 4.9 | 7.6 | 9 |
| No. 6. Springfield, long-range. | Peep and globe; Sharps'. | 80 | Unknown..... | 500 | .4555 | Frankford, $\frac{1}{17}$ tin | 1 | 7.2 | 4.9 | 8.7 |
| Do........ | ....do ......... | 80 | Hazard musket | 500 | .4555 | Springfield, $\frac{1}{18}$ tin | 1 | 3.1 | 6.6 | 7.3 |
| No. 7. Springfield, long-range. | Open service ... | 80 | Unknown ..... | 500 | .4555 | Frankford, $\frac{1}{17}$ tin | 1 | 6.9 | 7.2 | 9.[illegible] |
| Do....... | ....do ......... | 80 | Hazard musket | 500 | .4555 | Springfield, $\frac{1}{18}$ tin | 1 | 7.4 | 6.2 | 9.7 |
| No. 8. Service, long-chamber. | Peep and globe; Sharps'. | 80 | ....do ........ | 500 | .4555 | ....do .......... | 1 | 3.3 | 3.9 | 5.1 |
| No. 9. Service; long-chamber. | Open service ... | 70 | Unknown ..... | 500 | .4555 | Frankford flat point, $\frac{1}{18}$ tin. | 1 | 6.3 | 6.7 | 9.2 |
| No. 10. Service. | Peep and globe; Sharps'. | 70 | ....do ........ | 500 | .4555 | ....do .......... | 1 | 4 | 4.4 | 6 |
| Do........ | ....do ......... | 70 | ....do ........ | 500 | .4555 | Frankford flat point, $\frac{1}{17}$ tin. | 1 | 3.9 | 4.4 | 5.9 |
| Do........ | ....do ......... | 70 | ....do ........ | 500 | .4555 | ....do .......... | 2 | 6.1 | 2.6 | 6.6 |
| | | | | | | | Mean | 5 | 3.5 | 6.2 |
| Do........ | ....do ......... | 70 | ....do ........ | 500 | .4555 | Frankford round point, $\frac{1}{18}$ tin. | 1 | 2.7 | 3.3 | 4.3 |
| No. 11. Service. | Open service ... | 70 | ....do ........ | 500 | .4555 | ....do . ........ | 1 | 2.4 | 5.6 | 6.1 |
| Do........ | ....do ......... | 70 | ....do ........ | 500 | .4555 | Frankford flat point, $\frac{1}{17}$ tin. | 1 | 4 2 | 4.8 | 6.4 |
| Do........ | ....do ......... | 70 | ....do ........ | 500 | .4555 | Frankford flat point, $\frac{1}{17}$ tin. | 1 | 4 | 4.4 | 6 |
| Do........ | ....do ......... | 70 | ....do ........ | 500 | .4555 | ....do .......... | 2 | 3.2 | 4.9 | 5.8 |
| | | | | | | | Mean | 3.6 | 4.6 | 5.9 |

500 *yards range.—March* 15, 1881.

[Strong wind from the left.]

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs* | | *Grs* | | | | | | |
| No. 5. Springfield, V long-range. | Peep and globe; Bull's. | 80 | Unknown..... | 500 | .455 | Frankford, $\frac{1}{17}$ tin | 1 | 4.6 | 6.6 | 8. |
| Do......... | ....do .......... | 80 | ....do ......... | 500 | .455 | ....do ......... | 2 | 5.3 | 10.3 | 11.6 |
| | | | | | | | Mean | 4.9 | 8.4 | 9.8 |
| No. 6. Springfield, V long-range. | Peep and globe; Sharps'. | 80 | ....do ......... | 500 | .455 | ....do ........... | 1 | 2.8 | 5.1 | 5.8 |
| Do......... | ....do .......... | 80 | ....do ......... | 500 | .455 | ....do ........... | 2 | 3.6 | 7.1 | 8. |
| | | | | | | | Mean | 3.2 | 6.1 | 6.9 |
| No. 7. Springfield, V long-range. | Open service.... | 80 | ....do ......... | 500 | .455 | ....do ........... | 1 | 6.4 | 6.2 | 8.9 |
| Do......... | ....do .......... | 80 | ....do ......... | 500 | .455 | ....do ........... | 2 | 3.9 | 6.3 | 7.4 |
| | | | | | | | Mean | 5.1 | 6.2 | 8.1 |
| No. 8. Service, long-chamber. | Peep and globe; Sharps'. | 80 | ....do ......... | 500 | .455 | ....do ........... | 1 | 4.6 | 9.8 | 10.8 |
| No. 9. Service, long-chamber. | Open service.... | 80 | ....do ......... | 500 | .455 | ....do ........... | 1 | 6.7 | 4.5 | 8.1 |
| No. 10. Service. | Peep and globe; Sharps'. | 70 | ....do ......... | 500 | .455 | Frankford round point, $\frac{1}{17}$ tin. | 1 | 4. | 4.6 | 6.1 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 3.9 | 3.2 | 5. |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 3 | 6.7 | 3.5 | 7.6 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 4 | 2.6 | 2.2 | 3.4 |
| | | | | | | | Mean | 4.3 | 3.4 | 5.5 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .435 | Frankford round point, $\frac{1}{12}$ tin. | 1 | 4.8 | 4.3 | 6.4 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 2.6 | 3.6 | 4.4 |
| | | | | | | | Mean | 3.7 | 3.9 | 5.4 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | Frankford flat point, $\frac{1}{17}$ tin. | 1 | 2.4 | 4.1 | 4.8 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 3.6 | 6.2 | 7.2 |
| | | | | | | | Mean | 3. | 5.1 | 6 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | Frankford flat point, $\frac{1}{12}$ tin. | 1 | 5.2 | 2.4 | 5.7 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 2.7 | 4.8 | 5.5 |
| | | | | | | | Mean | 3.9 | 3 6 | 5.6 |

500 *yards range.—March* 15, 1881.

[Strong wind from the left; gusty.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. 11. Service. | Open service.... | 70 | Unknown ..... | 500 | .455 | Frankford round point, $\frac{1}{17}$ tin. | 1 | 3.4 | 4.5 | 5.6 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 6.8 | 5.5 | 8.8 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 3 | 5.3 | 5 | 7.3 |
| Do......... | ....dd .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 4 | 6.3 | 5.5 | 8.4 |
| | | | | | | | Mean | 5.4 | 5.1 | 7.5 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | Frankford round point, $\frac{1}{12}$ tin. | 1 | 4. | 4.4 | 6. |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 5.5 | 2.9 | 6.2 |
| | | | | | | | Mean | 4.7 | 3.1 | 6.1 |

500 *yards range.—March* 15, 1881—Continued.

[Strong wind from the left; gusty.]

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs* | | *Grs* | | | | | | |
| No. 11. Service. | Open service... | 70 | Unknown..... | 500 | .455 | Frankford flat point, 1/17 tin. | 1 | 3.9 | 3.5 | 5.2 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 6.2 | 2.2 | 6.6 |
| | | | | | | | Mean | 5 | 2.8 | 5.9 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | Frankford flat point, 1/13 tin. | 1 | 4.1 | 3. | 5.1 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 4 | 5.2 | 6.6 |
| | | | | | | | Mean | 4 | 4.1 | 5.8 |

500 *yards range.—March* 16, 1881.

[Very strong wind from the left.]

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| No. 10. Service. | Peep and globe; Sharps'. | 70 | Unknown..... | 500 | .455 | Frankford flat point, 1/13 tin. | 1 | 5.1 | 2.8 | 5.8 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 2.9 | 4.8 | 5.6 |
| | | | | | | | Mean | 4. | 3.8 | 5.7 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | Frankford, flat point, 1/17 tin. | 1 | 4.8 | 2.5 | 5.4 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 5.6 | 3.2 | 6.5 |
| | | | | | | | Mean | 5.2 | 2.8 | 5.9 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | Frankford round point, 1/13 tin. | 1 | 5.3 | 2.4 | 5.8 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 4.9 | 2.8 | 5.8 |
| | | | | | | | Mean | 5.1 | 2.6 | 5.8 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | Frankford round point, 1/17 tin. | 1 | 4.6 | 2.9 | 5.4 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 3.4 | 6. | 6.9 |
| | | | | | | | Mean | 4. | 4.4 | 6.1 |
| No. 11. Service. | Open service.... | 70 | ....do ......... | 500 | .455 | Frankford flat point, 1/13 tin. | 1 | 4.2 | 2.9 | 5.1 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 5.8 | 3.1 | 6.6 |
| | | | | | | | Mean | 5. | 3. | 5.8 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | Frankford flat point, 1/17 tin. | 1 | 5.1 | 3.3 | 6.1 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 3.7 | 2.6 | 4.5 |
| | | | | | | | Mean | 6.9 | 2.9 | 5.3 |
| Do......... | ... do .......... | 70 | ....do ......... | 500 | .455 | Frankford round point, 1/13 tin. | 1 | 5. | 4.7 | 6.9 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 4.5 | 4.6 | 6.4 |
| | | | | | | | Mean | 4.7 | 4.6 | 6.6 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | Frankford round point, 1/17 tin. | 1 | 5. | 7.1 | 8.7 |
| Do......... | ....do .......... | 70 | ....do ......... | 500 | .455 | ....do ........... | 2 | 6.8 | 3.6 | 7.7 |
| | | | | | | | Mean | 5.9 | 5.3 | 8.2 |

800 *yards range.—March* 7, 1881.

| Rifle. | Sight. | Powder. |  | Bullet. |  |  | No. of targets. | Deviations. |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Weight. | Kind. | Weight. | Caliber. | Kind. |  | M. H. | M. A. | M. V. |
|  |  | *Grs.* |  | *Grs.* |  |  |  |  |  |  |
| No. 1. Spring-field, special. | Peep and globe; Sharps'. | 80 | Hazard, F. G. | 500 | .4555 | Frankford, $\frac{1}{10}$ tin. | 1 | 8.4 | 9.8 | 4.9 |
| No. 2. Spring-field, special. | ....do | 80 | ....do | 500 | .4555 | ....do | 1 | 6.4 | 13.3 | 11.7 |
| No. 3. Spring-field, special. | ....do | 80 | ....do | 500 | .4555 | ....do | 1 | 10.3 | 13.5 | 8.7 |
| No. 6. Spring-field, long-range. | ....do | 80 | ....do | 500 | .4355 | ....do | 1 | 6.4 | 10.1 | 7.8 |
| No. 7. Spring-field, long-range. | Service | 80 | ....do | 500 | .4655 | ....do | 1 | 8.7 | 12.5 | 9. |
| No. 8. Service, long-chamber. | Peep and globe; Sharps'. | 80 | ....do | 500 | .4555 | ....do | 1 | 12.7 | 19. | 14.1 |
| No. 9. Service, long-chamber. | Service | 80 | ....do | 500 | .4555 | ....do | 1 | 13.2 | 17.6 | 11.6 |
| No. 10. Service. | Peep and globe; Sharps'. | 70 | ....do | 500 | .4555 | ....do | 1 | 6.8 | 9.5 | 6.6 |
| No. 11. Service. | Service | 70 | ....do | 500 | .4555 | ....do | 1 | 8.9 | 12.7 | 9.1 |

800 *yards range.—March* 8, 1881.

| Rifle. | Sight. | Powder weight. | Powder kind. | Bullet weight. | Caliber. | Bullet kind. | No. of targets. | M. H. | M. A. | M. V. |
|---|---|---|---|---|---|---|---|---|---|---|
| No. 1. Spring-field, special. | Peep and globe; Sharps'. | 80 | Hazard, F. G. | 500 | .4555 | Frankford, $\frac{1}{10}$ tin. | 1 | 10.4 | 16.9 | 19.8 |
| No. 2. Spring-field, special. | ....do | 80 | ....do | 500 | .4555 | ....do | 1 | 7.6 | 12.1 | 14.3 |
| No. 3. Spring-field, special. | ....do | 80 | ....do | 500 | .4555 | ....do | 1 | 7.3 | 15.4 | 17. |
| No. 4. Spring-field, special. | Peep and globe; Springfield. | 80 | ....do | 500 | .4555 | ....do | 1 | 7.5 | 14.5 | 16.3 |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 2 | 6.9 | 11.5 | 13.4 |
|  |  |  |  |  |  |  | Mean | 7.2 | 13. | 14.8 |
| No. 5. Spring-field, long-range. | Peep and globe; Bull's. | 80 | ....do | 500 | .4555 | ....do | 1 | 11.4 | 19.6 | 22.7 |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 2 | 8.5 | 7.7 | 11.5 |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 3 | 3.8 | 17.6 | 18. |
|  |  |  |  |  |  |  | Mean | 7.9 | 15. | 17.4 |
| No. 6. Spring-field, long-range. | Peep and globe; Sharps'. | 80 | ....do | 500 | .4535 | ....do | 1 | 11.5 | 18.7 | 22. |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 2 | 6. | 20.3 | 21.2 |
|  |  |  |  |  |  |  | Mean | 8.7 | 19.5 | 21.6 |
| No. 7. Spring-field, long-range. | Service | 80 | ....do | 500 | .4555 | ....do | 1 | 9.5 | 8.4 | 12.7 |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 2 | 6.4 | 11.7 | 13.3 |
|  |  |  |  |  |  |  | Mean | 7.9 | 10. | 13. |
| No. 8. Service; long-chamber. | Peep and globe; Sharps'. | 80 | ....do | 500 | .4855 | ....do | 1 | 13.6 | 22.8 | 26.6 |
| No. 9. Service; long-chamber. | Service | 80 | ....do | 500 | .4555 | ....do | 1 | 11.3 | 13.4 | 17.5 |
| No. 10. Spring-field; service. | Peep and globe; Sharps'. | 70 | ....do | 500 | .4555 | ....do | 1 | 6.4 | 11.9 | 13.5 |
| No. 11. Spring-field; service. | Service | 70 | ....do | 500 | .4555 | ....do | 1 | 8. | 13.1 | 15.3 |

800 *yards range.—March* 12, 1881.

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | | | |
| No. 1. Springfield, special. | Peep and globe; Sharps'. | 80 | Unknown | 500 | .4555 | Frankford, $\frac{1}{17}$ tin. | 1 | 10.8 | 12.9 | 16.8 |
| No. 2. Springfield, special. | ....do .......... | 80 | ....do .... | 500 | .4555 | ....do .......... | 1 | 6.9 | 14.1 | 15.7 |
| No. 3. Springfield, special. | ....do .......... | 80 | ....do .... | 500 | .4555 | ... do .......... | 1 | 9.7 | 7.9 | 12.5 |
| No. 4. Springfield, special. | Peep and globe; Springfield. | 80 | ... do .... | 500 | .4555 | ....do .......... | 1 | 8.4 | 18.2 | 20.0 |
| No. 6. Springfield, long-range. | Peep and globe; Sharps'. | 80 | ... do .... | 500 | .4555 | ....do .......... | 1 | 10.8 | 18.6 | 21.5 |
| No. 7. Springfield, long-range. | Service ........ | 80 | ....do .... | 500 | .4555 | ....do .......... | 1 | 9.4 | 8.1 | 12.4 |
| No. 8. Service, long-chamber. | Peep and globe; Sharps'. | 80 | ....do .... | 500 | .4555 | ....do .......... | 1 | 10.1 | 13.1 | 16.5 |
| No. 9. Service, long-chamber. | Service ........ | 80 | ... do .... | 500 | .4555 | ....do .......... | 1 | 17.7 | 19.9 | 26.6 |
| No. 10. Service. | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 8.8 | 16. | 18.3 |
| No. 11. Service. | Service ........ | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 12.1 | 22. | 25.1 |

800 *yards range.—March* 21, 1881.

[Strong wind from the right and rear.]

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| No. 1. Springfield, special. | Peep and globe; Sharps'. | 70 | Unknown | 500 | .4553 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 10.8 | 13.3 | 17.1 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 7 | 8.3 | 10.9 |
| No. 2. Springfield, special. | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 11.3 | 8.8 | 14.3 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 8.2 | 8. | 11.5 |
| No. 3. Springfield, special. | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 10.8 | 11.8 | 16 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 9.1 | 10.1 | 13.6 |
| No. 4. Springfield, special. | Peep and globe; Springfield. | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 9 | 8.7 | 12.5 |
| Do .......... | ....do .......... | 70 | ....do . | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 12.7 | 6.9 | 14.5 |
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 6.1 | 10.4 | 12.1 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 8.1 | 12.1 | 14.6 |
| No. 6. Springfield, long-range. | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 13.4 | 6.1 | 14.7 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 12.6 | 12.5 | 17.8 |
| No. 7. Springfield, long-range. | Open service .. | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 13.0 | 12.1 | 17.8 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 6.1 | 9.9 | 11.6 |
| No. 8. Service, long-chamber. | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 7.9 | 14.3 | 16.3 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 10.2 | 16.5 | 19.4 |
| No. 9. Service, long-chamber. | Open service ... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 11.7 | 10.1 | 15.5 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 7.8 | 10.6 | 13.2 |
| No. 10. Service | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 12.4 | 8.8 | 15.2 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 18.4 | 11.5 | 21.7 |
| No. 11. Service | Open service ... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 15.8 | 13.8 | 20.7 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | Frankford; flat point, $\frac{1}{17}$ tin. | 1 | 9.8 | 12 | 51.2 |

800 *yards range.—March* 22, 1881.

[Fresh breeze from left and front.]

| Rifle. | Sight. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Weight. | Kind. | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| | | *Grs.* | | *Grs.* | | | | | | |
| No. 1. Springfield, special. | Peep and globe; Sharps'. | 70 | Unknown | 500 | .4555 | Frankford; round point, 1/16 tin. | 1 | 11.7 | 8.5 | 14.5 |
| No. 2. Springfield, special. | ....do .......... | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 6.6 | 17.1 | 18.3 |
| No. 3. Springfield, special. | ....do .......... | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 8.7 | 12.3 | 15.1 |
| No. 4. Springfield, special. | Peep and globe; Springfield. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 12.5 | 14.1 | 18.8 |
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 6.9 | 10.2 | 12.3 |
| No. 6. Springfield, long-range. | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 8.9 | 17.0 | 19.2 |
| No. 7. Springfield, long-range. | Open service .. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 14.0 | 13.1 | 19.2 |
| No. 8. Service, long-chamber | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 14.9 | 9.2 | 17.5 |
| No. 9. Service, long-chamber | Open service... | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 9.4 | 17.5 | 19.9 |
| No. 10. Service. | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 11.1 | 11.6 | 16.1 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | ....do .......... | 2 | 11.2 | 13.5 | 17.5 |
| | | | | | | | Mean | 11.1 | 12.5 | 16.8 |
| No. 11. Service | Open service... | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 13.2 | 13.4 | 18.8 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | ....do .......... | 2 | 7.9 | 15.1 | 17 |
| | | | | | | | Mean | 10.5 | 14.2 | 17.9 |
| No. 1. Springfield, special. | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4555 | Frankford; round point, 1/16 tin. | 1 | 7.5 | 18.9 | 20.3 |
| No. 2. Springfield, special. | ....do .......... | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 8.3 | 11.5 | 14.2 |
| No. 3. Springfield, special. | ....do .......... | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 9.5 | 9.3 | 13.5 |
| No. 4. Springfield, special. | Peep and globe; Springfield. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 9.5 | 6.8 | 11.7 |
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 6.4 | 8.4 | 10.6 |
| No. 6. Springfield, long-range. | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 7. | 19.3 | 20.6 |
| No. 7. Springfield, long-range. | Open service... | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 10.6 | 14.3 | 17.8 |
| No. 8. Service, long-chamber. | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 7.0 | 18.9 | 20.1 |
| No. 9. Service, long-chamber. | Open service... | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 7.6 | 14.6 | 16.5 |
| No. 10. Service | Peep and globe; Sharps'. | 70 | ....do .... | 500 | .4355 | ....do .......... | 1 | 5.0 | 11.6 | 12.6 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4555 | ....do .......... | 2 | 7.1 | 12.4 | 14.3 |
| | | | | | | | Mean | 6 | 12 | 13.4 |
| No. 11. Service | Open service... | 70 | ....do .... | 500 | .4555 | ....do .......... | 1 | 11.7 | 13.1 | 17.6 |
| Do .......... | ....do .......... | 70 | ....do .... | 500 | .4355 | ....do .......... | 2 | 13.4 | 19.1 | 23.3 |
| | | | | | | | Mean | 12.5 | 16.1 | 20.4 |

800 *yards range.—March* 23, 1881.

[Fresh breeze from the left and rear.]

| Rifle. | Sight. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Weight. | Kind. | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| | | *Grs.* | | *Grs.* | | | | | | |
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 70 | Unknown | 500 | .4555 | Frankford; flat point, ⅓ tin. | 1 | 4.1 | 19.5 | 19.9 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; flat point, ⅓ tin. | 1 | 4.6 | 16.4 | 17.0 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; round point, ⅓ tin. | 1 | 12.5 | 12.4 | 17.6 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; round point, ⅓ tin. | 1 | 14.3 | 9.2 | *17 |
| No. 6. Springfield, long-range. | Peep and globe; Sharps'. | 70 | ....do | 500 | .4555 | Frankford; flat point, ⅓ tin. | 1 | 12.8 | 19.1 | 23.0 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; flat point, ⅓ tin. | 1 | 11.6 | 19.8 | 22.9 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; round point, ⅓ tin. | 1 | 7. | 8.3 | 10.8 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; round point, ⅓ tin. | 1 | 5. | 12.8 | *13.7 |
| No. 7. Springfield, long-range. | Open service | 70 | ....do | 500 | .4555 | Frankford; flat point, ⅓ tin. | 1 | 11.7 | 19.9 | 23.2 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; flat point, ⅓ tin. | 1 | 8. | 15.5 | 17.5 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; round point, ⅓ tin. | 1 | 8. | 13.6 | 15.8 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; round point, ⅓ tin. | 1 | 21.6 | 9.4 | *23.6 |
| No. 10. Service. | Peep and globe; Sharps'. | 70 | ....do | 500 | .4555 | Frankford; flat point, ⅓ tin. | 1 | 7.9 | 12.7 | 15.0 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; flat point, ⅓ tin. | 1 | 9.7 | 10.8 | 14.5 |
| Do | ....do | 70 | ....do | 509 | .4505 | Frankford; round point, ⅓ tin. | 1 | 11.8 | 12.8 | 17.4 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; round point, ⅓ tin. | 1 | 9.3 | 13.4 | *16.3 |
| No. 11. Service. | Open service | 70 | ....do | 500 | .4555 | Frankford; flat point, ⅓ tin. | 1 | 9.8 | 11.2 | 14.9 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; flat point, ⅓ tin. | 1 | 4.1 | 16.4 | 16.9 |
| Do | ....do | 70 | ....do | 500 | .4655 | Frankford; round point, ⅓ tin. | 1 | 11.8 | 6.5 | 13.5 |
| Do | ....do | 70 | ....do | 500 | .4555 | Frankford; round point, ⅓ tin. | 1 | 11.2 | 20.9 | *23.7 |

* Strong wind, gusty.

800 *yards range.—April* 27, 1881.

[Calm.]

| Rifle. | Sight. | Powder. | | Bullet. | | | No. of targets. | Mean deviations. |
|---|---|---|---|---|---|---|---|---|
| | | Weight. | Kind. | Weight. | Caliber. | Kind. | | |
| | | *Grs.* | | *Grs.* | | | | |
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 80 | Unknown | 500 | .4555 | Frankford | 1 | 11.7 |
| No. 13. Sharps', long-range. | Peep and globe; Sharps'. | 100 | Hazard S. M. | 550 | ...... | Patched | 1 | 11.2 |

### 800 *yards range.—April* 28, 1881.

[Strong and gusty wind.]

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Mean deviations. |
|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | |
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 90 | Hazard S. M. | 550 | .458 | Springfield | 1 | *13.7 |
| Do | ....do | 90 | ....do | 550 | .45 | ....do | 2 | 16.0 |
| | | | | | | | Mean | 14.8 |

### 800 *yards range.—May* 2, 1881.

[Calm.]

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Mean deviations. |
|---|---|---|---|---|---|---|---|---|
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 90 | Hazard S. M. | 550 | .458 | Springfield | 1 | *12.7 |
| Do | ....do | 90 | ....do | 550 | ...... | ....do | 2 | *14.6 |
| | | | | | | | Mean | 13.6 |
| No. 13. Sharps', long-range. | Peep and globe; Sharps'. | 100 | Hazard S. M. | 550 | ...... | Patched | 1 | *7.1 |

### 800 *yards range.—May* 3, 1881.

[Strong wind from right and rear.]

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Mean deviations. |
|---|---|---|---|---|---|---|---|---|
| No. 5. Springfield, long-range. | Peep and globe; Bull's. | 80 | Hazard S. M. | 550 | .458 | Springfield | 1 | *23.7 |
| No. 13. Sharps', long-range. | Peep and globe; Sharps'. | 100 | ....do | 550 | ...... | Patched | 1 | *14.4 |

* Gun cleaned after every shot.

### 800 *yards range.—June* 6, 1881.

[Calm.]

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Mean deviations. |
|---|---|---|---|---|---|---|---|---|
| No. 12. Springfield special, Hotchkiss system, long-chambered. | Peep and globe; Bull's. | 70 | Service | 405 | .458 | Service | 1 | 32.1 |
| Do | ....do | 70 | Unknown | 500 | .4555 | Frankford | 1 | 19.4 |
| Do | ....do | 70 | ....do | 500 | .4555 | ....do | 2 | 23.4 |
| | | | | | | | Mean | 21.4 |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 1 | 17.7 |
| Do | ....do | 80 | ....do | 500 | .4535 | ....do | 2 | 17.7 |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 3 | 11.5 |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 4 | 21.1 |
| | | | | | | | Mean | 17.0 |
| Do | ....do | 80 | Hazard S. M. | 492 | .4555 | Springfield; ½ tin. | 1 | 14.0 |
| Do | ....do | 80 | ....do | 500 | .4555 | Springfield | 1 | 19.2 |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 2 | 17.3 |
| | | | | | | | Mean | 18.2 |
| Do | ....do | 80 | ....do | 550 | .458 | ....do | 1 | 13.2 |
| Do | ....do | 80 | ....do | 550 | .458 | ....do | 1 | 10.8 |
| Do | ....do | 90 | ....do | 550 | .458 | ....do | 2 | 21.7 |
| Do | ....do | 90 | ....do | 550 | .458 | ....do | 3 | 24.1 |
| | | | | | | | Mean | 18.9 |
| No. 13. Springfield special, Sharps' system, long-chambered. | Peep and globe; Sharps'. | 80 | Unknown | 500 | .458 | Frankford | 1 | 16.1 |
| Do | ....do | 80 | Hazard S. M. | 492 | .458 | Springfield; ½ tin. | 1 | 17.7 |
| Do | ....do | 80 | ....do | 500 | .458 | Springfield | 1 | 16.5 |

800 *yards range.—June* 7, 1881.

[Calm.]

| Rifle. | Sight. | Powder. | | Bullet. | | | No. of targets. | Mean deviations. |
|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Weight. | Caliber. | Kind. | | |
| | | *Grs.* | | *Grs.* | | | | |
| No. 12. Springfield special, Hotchkiss system, long-chambered. | Peep and globe; Bull's. | 70 | Hazard S. M. | 500 | .4555 | Springfield.. | 1 | 21.8 |
| Do | ....do | 70 | ....do | 500 | .4555 | ....do | 2 | 30.3 |
| | | | | | | | Mean. | 26.0 |
| Do | ....do | 70 | Unknown | 500 | .4555 | Frankford.. | 1 | 27.3 |
| Do | ....do | 70 | ....do | 500 | .4555 | ....do | 2 | 16.2 |
| | | | | | | | Mean. | 21 7 |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 1 | 12.7 |
| Do | ....do | 80 | ....do | 500 | .4555 | ....do | 2 | 18.6 |
| | | | | | | | Mean. | 15.6 |
| Do | ....do | 80 | Hazard S. M. | 500 | .4555 | Springfield.. | 1 | 18.7 |
| Do | ....do | 80 | ....do | 550 | .458 | ...do | 1 | 22.1 |
| Do | ....do | 90 | ....do | 550 | .458 | ....do | 1 | 24.5 |

[Wind velocity, 12 miles per hour, from left and front.]

| Rifle. | Sight. | Powder (Grs.) | Powder kind | Weight | Caliber | Bullet kind | No. of targets | Mean deviations |
|---|---|---|---|---|---|---|---|---|
| No. 11. Service | Service | 70 | Unknown | 500 | .458 | Frankford.. | 1 | 20. |
| Do | ....do | 70 | ....do | 500 | .458 | ....do | 2 | 22.2 |
| Do | ....do | 70 | ....do | 500 | .458 | ....do | 3 | 13.5 |
| Do | ....do | 70 | ....do | 500 | .458 | ....do | 4 | 18. |
| | | | | | | | Mean. | 18.4 |
| No. 12. Springfield special, Hotchkiss system, long-chambered. | Peep and globe; Bull's. | 80 | ....do | 500 | .458 | ....do | 1 | 14.6 |
| Do | ......do | 80 | ....do | 500 | .458 | ....do | 2 | 16.5 |
| | | | | | | | Mean. | 15.5 |
| No. 3. Springfield special, long-chambered. | Peep and globe; Sharp's. | 80 | ....do | 500 | .458 | ....do | 1 | 14.9 |
| Do | ... do | 80 | ....do | 500 | .458 | ....do | 2 | 18.7 |
| Do | ....do | 80 | ....do | 500 | .458 | ....do | 3 | 14.4 |
| | | | | | | | Mean. | 16.0 |

800 *yards range.—June* 11, 1881.

[Fresh breeze from left and front.]

| Rifle. | Sight. | Powder (Grs.) | Powder kind | Weight | Caliber | Bullet kind | No. of targets | Mean deviations |
|---|---|---|---|---|---|---|---|---|
| No. 2. Springfield special. | Peep and globe; Sharps'. | 80 | Unknown | 500 | .4555 | Frankford.. | 1 | 13.5 |
| No. 3. Springfield special. | ......do | 80 | ....do | 500 | .4555 | ....do | 1 | 12.0 |
| No. 4. Springfield special. | Peep and globe; Springfield. | 80 | ....do | 500 | .4555 | ....do | 1 | 20.9 |
| No. 8. Service, long-chamber. | Peep and globe; Sharps'. | 80 | ....do | 500 | .4555 | ....do | 1 | 9.9 |
| No. 12. Springfield special, Hotchkiss system. | Peep and globe; Bull's. | 80 | ....do | 500 | .4555 | ....do | 1 | 13.8 |
| No. 13. Springfield special, Sharps' system. | Peep and globe; Sharps'. | 80 | ....do | 500 | .4555 | ....do | 1 | 16.8 |
| No. 2. Springfield special. | ....do | 70 | ....do | 500 | .4555 | ....do | 1 | 13.7 |
| No. 3. Springfield special. | ....do | 70 | ....do | 500 | .4555 | ....do | 1 | 22.7 |
| No. 4. Springfield special. | Peep and globe; Springfield. | 70 | ....do | 500 | .4555 | ....do | 1 | 23.9 |
| No. 8. Service, long-chamber. | Peep and globe; Sharps'. | 70 | ....do | 500 | .4555 | ....do | 1 | 23.2 |
| No. 12. Springfield special, Hotchkiss system. | Peep and globe; Bull's. | 70 | ....do | 500 | .4555 | ....do | 1 | 23.1 |
| No. 13. Springfield special, Sharps' system. | Peep and globe; Sharps'. | 70 | ....do | 500 | .4555 | ....do | 1 | 20.5 |

**800 *yards range.—June* 13, 1881.**

[Light breeze from left and rear.]

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | | | |
| No. 1. Springfield, special. | Peep and globe. Sharps'. | 80 | Unknown | 500 | .4555 | Frankford | 1 | 7.4 | 7.8 | 10.7 |
| Do | ...do | 80 | ...do | 500 | .4555 | ...do | 2 | 7.5 | 12.8 | 14.8 |
| | | | | | | | Mean | 7.4 | 20.3 | 12.7 |
| No. 2. Springfield, special. | ...do | 80 | ...do | 500 | .4555 | ...do | 1 | 7.6 | 9.6 | 12.2 |
| No. 3. Springfield, special. | ...do | 80 | ...do | 500 | .4555 | ...do | 1 | 8.9 | 5.6 | 10.5 |
| No. 4. Springfield, special. | Peep and globe. Springfield. | 80 | ...do | 500 | .4555 | ...do | 1 | 7.6 | 5.9 | 9.6 |
| No. 8. Service, long chamber. | Peep and globe. Sharps'. | 80 | ...do | 500 | .4555 | ...do | 1 | 8.4 | 14.1 | 16.4 |
| No. 12. Springfield, special; Hotchkiss system. | Peep & globe. Bull's. | 80 | ...do | 500 | .4555 | ...do | 1 | 9.8 | 7.8 | 12.5 |
| | | | | | | | 2 | 8.2 | 12.2 | 14.7 |
| | | | | | | | Mean | 9.0 | 10.0 | 13.6 |
| No. 13. Springfield, special; Sharps system. | Peep and globe. Sharps'. | 80 | ...do | 500 | .4555 | ...do | 1 | 10.7 | 8.4 | 13.6 |
| No. 1. Springfield, special. | ...do | 70 | ...do | 500 | .4555 | ...do | 1 | 14.7 | 10.3 | 17.9 |
| Do | ...do | 70 | ...do | 500 | .4555 | ...do | 2 | 10.0 | 10.0 | 14.1 |
| | | | | | | | Mean | 12.3 | 10.1 | 16.0 |
| No. 2. Springfield, special. | ...do | 70 | ...do | 500 | .4555 | ...do | 1 | 15.9 | 14.2 | 21.3 |
| No. 3. Springfield, special. | ...do | 70 | ...do | 500 | .4555 | ...do | 1 | 16.7 | 14.0 | 21.8 |
| No. 4. Springfield, special. | Peep and globe. Springfield. | 70 | ...do | 500 | .4555 | ...do | 1 | 6.6 | 19.6 | 20.7 |
| No. 8. Service, long chamber. | Peep and globe. Sharps'. | 70 | ...do | 500 | .4555 | ...do | 1 | 16.0 | 21.4 | 26.7 |
| No. 12. Springfield, special; Hotchkiss system. | Peep & globe. Bull's. | 70 | ...do | 500 | .4555 | ...do | 1 | 15.9 | 11.1 | 19.4 |
| | | | | | | | 2 | 6.7 | 12.2 | 13.9 |
| | | | | | | | Mean | 11.3 | 11.6 | 16.6 |
| No. 13. Springfield, special; Sharps system. | Peep and globe. Sharps'. | 70 | ...do | 500 | .4555 | ...do | ...... | 15.6 | 11.8 | 19.6 |

**200 *yards range.—February* 26, 1881.**

| Rifle. | Twist. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | | | |
| Service | Right | 70 | Dupont | 500 | .4555 | Springfield | 1 | 2.8 | 2.4 | 3.7 |
| Do | Left | 70 | ...do | 500 | .4555 | ...do | 2 | 1. | 1.4 | 1.7 |
| Hotchkiss | Right | 70 | ...do | 500 | .4555 | ...do | 3 | 1.4 | 2.5 | 2.9 |
| Do | Left | 70 | ...do | 500 | .4555 | ...do | 4 | 2.5 | 1.6 | 3.0 |
| Service | Right | 70 | ...do | 500 | .4555 | ...do | 5 | 2.1 | 2.5 | 3.3 |
| Do | Left | 70 | ...do | 500 | .4555 | ...do | 6 | 1.3 | 1.8 | 2.2 |
| Hotchkiss | Right | 70 | ...do | 500 | .4555 | ...do | 7 | 1.2 | 2.3 | 2.6 |
| Do | Left | 70 | ...do | 500 | .4555 | ...do | 8 | 1.9 | 2.1 | 2.8 |
| | | | | | | | Mean | 1.8 | 2.07 | 2.8 |

400 *yards range.—February* 26, 1881.

| Rifle. | Twist. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | | | |
| Service | Right. | 70 | Dupont. | 500 | .4555 | Springfield. | 1 | 7.0 | 2.3 | 7.4 |
| Do | Left | 70 | ..do | 500 | .4555 | ....do | 2 | 5.5 | 2.9 | 6.2 |
| Hotchkiss | Right. | 70 | ..do | 500 | .4555 | ....do | 3 | 5.7 | 4.7 | 7.4 |
| Do | Left | 70 | ..do | 500 | .4555 | ....do | 4 | 3.4 | 3.7 | 5.0 |
| Service | Right. | 70 | ...do | 500 | .4555 | ....do | 5 | 4.9 | 6.7 | 8.3 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 6 | 3.1 | 2.6 | 4.9 |
| Hotchkiss | Right. | 70 | ...do | 500 | .4555 | ....do | 7 | 5.1 | 5.2 | 7.3 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 8 | 3.0 | 3.3 | 4.5 |
| | | | | | | | Mean | 4.7 | 3.9 | 6.26 |

600 *yards range.—February* 26, 1881.

| Rifle. | Twist. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | | | |
| Service | Right. | 70 | Dupont. | 500 | .4555 | Springfield.. | 1 | 5.8 | 4.9 | 7.6 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 2 | 5.5 | 5. | 7.4 |
| Hotchkiss | Right. | 70 | ...do | 500 | .4555 | ....do | 3 | 5.4 | 7.3 | 9.1 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 4 | 6.8 | 4.4 | 7.0 |
| Service | Right. | 70 | ...do | 500 | .4555 | ....do | 5 | 5.8 | 5.1 | 7.4 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 6 | 5.4 | 8.8 | 10.3 |
| Hotchkiss | Right | 70 | ...do | 500 | .4555 | ....do | 7 | 8.3 | 2.4 | 8.6 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 8 | 6.1 | 5.5 | 8.3 |
| | | | | | | | Mean | 6.01 | 5.4 | 8.2 |

800 *yards range.—February* 16, 1881.

| Rifle. | Twist. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | | | |
| Service | Right. | 70 | Dupont. | 500 | .4555 | Springfield. | 1 | 5.6 | 3.6 | 6.7* |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 2 | 10. | 7.5 | 12.5 |
| Hotchkiss | Right. | 70 | ...do | 500 | .4555 | ....do | 3 | 7.2 | 9.1 | 11.6 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 4 | 9.5 | 5.9 | 11.2 |
| Service | Right. | 70 | ...do | 500 | .4555 | ....do | 5 | 7.9 | 10.7 | 13.3 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 6 | 8.4 | 9.6 | 12.7 |
| Hotchkiss | Right. | 70 | ...do | 500 | .4555 | ....do | 7 | 8.4 | 7.8 | 11.5 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 8 | 7.8 | 9.8 | 12.5 |
| | | | | | | | Mean | 8.1 | 8.0 | 11.5 |

* Best recorded target at this range.

1,000 *yards range.—February* 16, 1881.

| Rifle. | Twist. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | | | |
| Service | Right. | 70 | Dupont | 500 | .4555 | Springfield | 1 | 15.1 | 19.0 | 24.2 |
| Hotchkiss | ..do | 70 | ...do | 500 | .4555 | ....do | 2 | 11.2 | 17.2 | 20.5 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 3 | 8.5 | 11.3 | 14.1 |
| Service | Right. | 70 | ...do | 500 | .4555 | ....do | 4 | 14. | 19.2 | 23.8 |
| Do | Left | 70 | ...do | 500 | .4555 | ....do | 5 | 11.6 | 18.6 | 21.9 |
| Hotchkiss | ..do | 70 | ...do | 500 | .4555 | ....do | 6 | 12.0 | 22.3 | 25.3 |
| | | | | | | | Mean. | 12.06 | 17.9 | 21.6 |

## APPENDIX 14.

### REPORT ON THE FABRICATION OF CENTERS FOR PAPER TARGETS "A," BY MAJOR D. W. FLAGLER, COMMANDING ROCK ISLAND ARSENAL, ILL.

(One plate.)

MARCH 25, 1881.

The centers are printed in an ordinary press on an engraved plate which was cast and engraved in the arsenal shops.

The only difficulty anticipated in making the targets was in finding some economical method of cutting the exact circle required, 24 inches in diameter, to fit into the first circle of the target. Such a circle in paper could not be cut by any of the ordinary methods employed for cutting paper cheaply with machinery, and the cost of laying out and cutting by hand would have been very great.

These were cut on a turning and boring mill in the machine shop. As the sheets came from the printing press, they were packed 2,500 in a wooden box without a cover, the *neat* sides of the paper (the sides with reference to which the printing was done) placed carefully against two sides of the box, and held there with wedges, to insure that the printed centers should all be packed exactly over each other. This box was then placed on the mill, centered, and a heavy circular iron plate, having the same diameter as the required paper circle, was placed on top of the pile of paper, centered and pressed down with all the force the mil center would allow, probably 3,000 pounds.

The sides of the wooden packing box were then removed, and the whole pile, 10 inches high, was then turned or cut off with a knife, fed precisely as a tool would be in turning the face of a pulley and as accurately. The knife required about the strength of a tool for turning iron. Its cutting edge was filed out into an arc of a circle having the same curvature as the circle to be cut, and then filed to about the slope that would be given to a knife in cutting paper by hand.

This process is described at some length, because parties experienced in cutting paper, whom I consulted, stated that a pile of paper could not possibly be cut in this way.

It shows that paper circles exact to one-hundredth of an inch, and of diameters as large as the capacity of the mill (the one at this arsenal will turn 8-feet diameters), can be cut in this way at a trifling cost. The cost of cutting these centers was 15 cents per 1,000.

The centers are turned to a diameter of 23¾ inches, ¼ inch less than the diameter of the inner ring of the A target, to leave a little margin for error in pasting on.

The centers are packed for issue in wooden packing boxes 1 inch deep, and 250 in each box (see inclosed drawing).

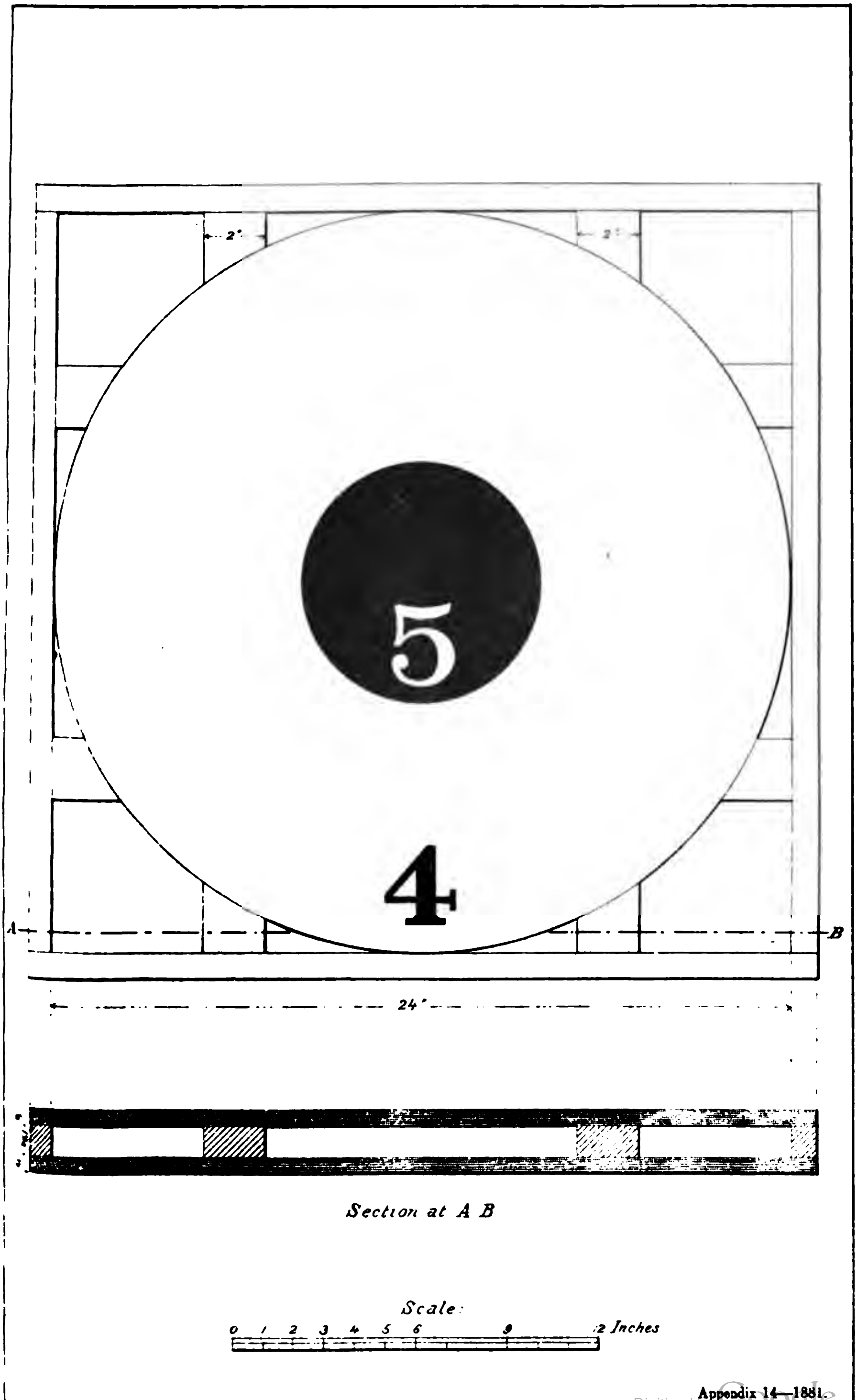
The boxes cost 28 cents each, are necessary to keep the centers in good order during transportation, and would be convenient for preserving the centers while in the hands of company commanders, until a box is used up. It is thought 250 centers might be made a unit of issue. They would cost, including packing box, about $2.50.

COST OF 1,000 CENTERS.

(The paper is purchased in sheets 25 inches square, and weighs 70 pounds per 1,000 sheets.)

| | |
|---|---|
| 70 pounds paper, at 9½ cents per pound | $6 65 |
| Printing | 1 50 |
| Cutting, counting, and packing | 50 |
| 4 packing boxes, at 28 cents each | 1 12 |
| Miscellaneous expenses | 23 |
| | 10 00 |

Per box of 250, $2.50.
The cost of engraved plate and special tools required was $11.00.


2"
2"
5
4
A
B
24"
Section at A B
Scale:
0 1 2 3 4 5 6 9 12 Inches

## APPENDIX 15.

**DESCRIPTION OF HARNESS MANUFACTURED AT ROCK ISLAND ARSENAL, FOR THE LAIDLEY CAVALRY FORGE, BY MAJOR W. D. FLAGLER, ORDNANCE DEPARTMENT.**

(One plate.)

### HARNESS FOR ONE LEAD-HORSE.

*Saddle.*—Cavalry, with stirrup-straps, stirrups, and web girth; *single-tree* attachment on rear, riveted through arc of saddle (rivets 1 inch by ¼-inch), and screwed on to the cantle with ¾-inch No. 12 iron screws.

One 1-inch square riveted on center of arc in rear, for attaching buck-strap; rivets Nos. 8 and 9; 2 tugs, each with 1-inch buckle, and standing loop sewed into the rings on the side bars in front of the pommel.

*Bridle, artillery.*—Off-horse, with coupling strap.

*Leg guard.*—Artillery.

*Traces.*—Two traces made of two thicknesses of leather, sewed with two seams, ⅜-inch thick, with cockeyes and S's on one end, fastened with rivets ¼-inch by ¾-inch. Holes punched in other end to buckle into breast strap.

*Breast strap.*—One body single leather, with under edges reduced so as not to gall the horse; 1 lay, containing in fold on each end two loops, and 1 1½-inch barrel-shaped roller trace buckle; 2 side straps sewed into 1¼-inch rings; these rings sewed between the lay and body of the breast collar, 7½ inches from each end; lay to be reduced ¼-inch in width between the side straps.

*Crupper.*—One dock made of leather folded lengthwise, with edges turned in; 1 ¾-inch buckle with loop sewed on each end; 1 body, the rear end split into two billets 8 inches long to buckle into the dock; 1 back-strap; the rear end is sewed on the body, forming a lay, which has a 1-inch buckle and three standing loops; an opening is made between the lay and body 11½ inches from the ends of dock billets for the loin strap to pass through.

*Loin strap.*—One loin strap, made of single leather, with holes punched in each end to buckle into the trace loops.

*Trace loops.*—Two trace loops, made of single leather, folded sufficiently to admit 1 loop and buckle ⅞-inch.

*Single-tree pad.*—One loop sewed on back with opening for back-strap to pass through and return; 1 leather lining sewed on back and filled with goat's hair.

### HARNESS FOR ONE WHEEL-HORSE.

*Bridle.*—One artillery briddle, off-horse, with coupling-strap and link.

*Saddle.*—One artillery valise saddle, having a brass frame with rollers, firmly fastened across the saddle 7 inches from the top of the pommel by eight brass screws, 1⅝-inch; No. 9 leather; 1 back-band made of two pieces of leather sewed together with two seams, to pass through frame and buckle into shaft tugs.

*Shaft tugs.*—Two shaft tugs made each of one piece of leather, folded

and sewed, with one loop, having in one end a 1½-inch buckle, in the other end the upper triangle of the hook attachment.

*Shaft-tug billets.*—Two billets, made of single leather, and sewed in the lower triangle of hook attachment.

*Belly-band.*—One belly-band, made of single leather, the buckles 1½-inch, fastened on each by chapes with one loop, and set far enough back for the projection to act as a safe.

*Collar.*—One artillery collar.

*Hames.*—One pair of artillery hames, with loops made in the bottom 1⅛-inch wide by ⅜-inch deep, for hame strap; 2 safes sewed around the hames under the joint loops to protect the collar; 2 hame straps; 1 collar strap.

*Hame tugs.*—Two hame tugs, each made of one piece of leather doubled and stitched on a safe, containing in the fold on one end the hame cockeye, on the other end the cockeye of chain for shaft attachment; thickness of hame tug, 0.375-inch.

*Breeching.*—Two breeching straps, firm leather, each with 1¼-inch buckle, and two loops in the fold, and one slide loop; 1 breeching body, single leather, under edges reduced as on breast strap; 1 lay; 1 D 1⅜-inch by 2 inches in each end of the fold, and sewed on to the body with two seams; width of lay between tugs reduced ¼-inch to correspond with breast strap; 4 breeching tugs, made of two thicknesses of leather, and sewed on to safes, each with three loops and 1⅜-inch buckle; two of the tugs to be sewed on to D at each end of the lay, the remaining two to have ⅞-inch squares in the bottom and sewed between the lay and body 7½ inches from each end; 2 hip straps of single leather to buckle into the breeching rings.

*Crupper.*—Made the same as for the lead-horse, with the exception of having two openings between the lay and body at distances of 10½ to 12½ inches from billet end, for hip straps to pass through.

*Dimensions of parts of Laidley forge cart harness manufactured at Rock Island Arsenal.*

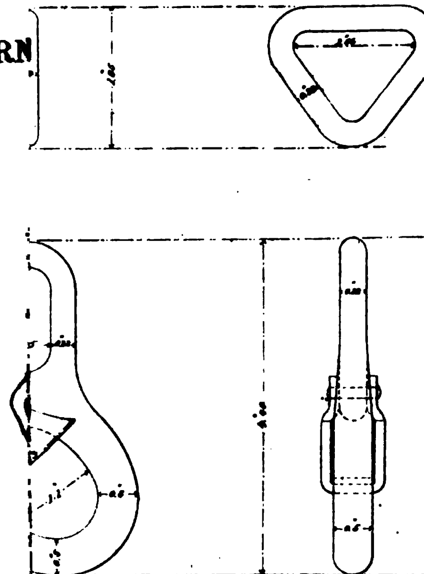
| | Number. | Width. | Length. | | Buckles. | |
|---|---|---|---|---|---|---|
| | | | Cut. | Finished. | Number. | Width. |
| LEAD HARNESS. | | *Inches.* | *Inches.* | *Inches.* | | *Inches.* |
| Saddle tugs | 2 | 1 | 5.5 | 2.25 | 2 | 1 |
| Traces | 2 | 1.5 | 72 | 72 | | |
| Loin straps | 1 | 0.875 | 60 | 60 | | |
| Trace loops | 2 | 0.875 | 13.5 | 6.25 | 2 | 0.875 |
| Breast strap: | | | | | | |
| Body | 1 | 2.25 | 43.25 | 43.25 | | |
| Lay | 1 | 1.5 | 51 | 42 | 2 | 1.5 |
| Side straps | 2 | 1 | 22 | 19.25 | | |
| Crupper: | | | | | | |
| Dock | 1 | 4 | 13.5 | 13.5 | 2 | 0.75 |
| Body | 1 | 1.75 | 18 | 18 | | |
| Back strap | 1 | 1 | 42 | 42 | 1 | 1 |
| Single-tree pad: | | | | | | |
| Loop | 1 | 2 | 4.5 | 4.5 | | |
| Back | 1 | 3 | 6.25 | 6.25 | | |
| Lining | 1 | 3.25 | 6.625 | | | |
| WHEEL HARNESS. | | | | | | |
| Saddle back band | 1 | 1.5 | 36 | 36 | | |
| Shaft tugs | 2 | 1.5 | 9 | 3.75 | 2 | 1.5 |
| Shaft-tug billets | 2 | 1.5 | 15 | 12.5 | | |
| Belly-band body | 1 | 2 | 25 | 25 | 2 | 1.5 |
| Hames: | | | | | | |
| Hame safes | 2 | 7 | 12.5 | 9.75 | | |
| Hame tugs | 2 | 1.5 | 29 | 13 | | |
| Hame-tug safes | 2 | 2.875 | 11.25 | 11.25 | | |
| Hame straps (bottom) | 1 | 1 | 22 | 19 | 1 | 1 |

*Dimensions of parts of Laidley forge cart harness manufactured at Rock Island Arsenal*—Continued.

| | Number. | Width. | Length. | | Buckles. | |
|---|---|---|---|---|---|---|
| | | | Cut. | Finished. | Number. | Width. |
| WHEEL HARNESS—Continued. | | *Inches.* | *Inches.* | *Inches.* | | *Inches.* |
| Breeching straps | 2 | 1.25 | 72 | 62 | 2 | 1.25 |
| Breeching: | | | | | | |
| Body | 1 | 2 | 42 | 42 | | |
| Lay | 1 | 1.25 | 51 | 43.5 | | |
| Tugs | 4 | 0.875 | 13 | 6 | 4 | 0.875 |
| Tug safes | 4 | 2 | 6.5 | 6.5 | | |
| Hip straps | 2 | 0.875 | 48 | 48 | | |
| Crupper: | | | | | | |
| Dock | 1 | 4 | 13.5 | 13.5 | 2 | 0.75 |
| Body | 1 | 1.75 | 18 | 18 | | |
| Back strap | 1 | 1 | 50 | 50 | 1 | 1 |

PLATE I.

HARN



Appendix 15—1861.

# APPENDIX 16.



## REPORT UPON CERTAIN TESTS FOR PHYSICAL PROPERTIES MADE WITH VARIOUS SIZES OF BAR-IRON USED IN THE FABRICATION OF WROUGHT-IRON TUBES FOR CONVERTED RIFLES, BY LIEUT. C. W. WHIPPLE, ORDNANCE DEPARTMENT, UNDER THE DIRECTION OF LIEUT. COL. S. CRISPIN, CONSTRUCTOR OF ORDNANCE.

In the construction of the first 8-inch converted rifles the wrought-iron tubes were made in England, and the tests to which the bar-iron used was subjected were those usual at the works of Sir William Armstrong, where the tubes were made. The specimens taken along the fiber were 2 inches in length between shoulders and about 0.580 inch in diameter.

The results obtained from numerous specimens were, approximately, as follows:

Tensile strength per square inch, 50,000 pounds.

Elastic limit per square inch, 25,000 pounds.

Extension per inch at rupture, 0''.30.

When the fabrication of the tubes was first undertaken by the West Point Foundry it was prescribed in the contract that the bar-iron should equal in all respects that used in the imported tubes; consequently it must have the same welding and physical properties and be equally free from excess of cinder.

The Ulster Iron Works undertook to furnish the West Point Foundry with such bar-iron, and by dint of perseverance and the utmost care have up to the present time produced a material of remarkable uniformity, which in all respects compares favorably with, and in some certainly surpasses, the English iron it at first aimed only to imitate.

In the report of the Chief of Ordnance for 1877, Capt. C. S. Smith describes the mode of manufacture of the iron, and gives comparisons between it and the English iron as regards physical and chemical properties.

The standard at first established has been closely adhered to since, though in 1877 the length of specimens between shoulders was increased from 2 to 3 inches, to adapt them to the device then adopted for measuring extensions and restorations; the method of proceeding has been as follows:

On the receipt of the first lot of iron, two specimens are taken from sample bars of each size of the two grades of iron used.* These specimens are tested in the machine at the Ordnance agency not only for tensile strength, elasticity, and ultimate extension, but for gradual extension, restoration, and permanent set; and if the iron prove satisfactory, it is accepted and the founders authorized to proceed with the work.

As subsequent lots arrive similar specimens are taken of each size of the two grades of iron, as before, and tested in the machine at the foundry for tensile strength and ultimate extension.

The following summary of the tests to which this iron has been sub-

*The two grades, denominated A and B, are used, respectively, for inner and outer tubes; their properties are almost identical, but the former, from additional working, contains less cinder.

jected since January, 1879, shows a degree of uniformity which has been attained in its manufacture:

| No. of specimen. | Size of bar. | Where tested. | Specimen. Diameter. | Specimen. Length. | Tensile strength. | Elastic limit. | Extension per inch at rupture. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | *Inch.* | *Inches.* | *Lbs. per sq. inch.* | *Lbs. per sq. inch.* | *Inch.* | |
| 1 | 2¼" square | Ordnance agency | 0.564 | 3.00 | 49,850 | 25,000 | 0.291 | A |
| 2 | 2¼" square | do | 0.564 | 3.00 | 47,500 | 28,000 | 0.3106 | A |
| 3 | 2¼" square | do | 0.564 | 3.00 | 46,500 | 25,000 | 0.2833 | A |
| 4 | 4" × 3".35 | West Point foundry | 0.564 | 2.00 | 47,552 | ........ | 0.31 | A |
| 5 | 4" × 3".35 | do | 0.564 | 2.00 | 47,304 | ........ | 0.29 | A |
| 6 | 2¼" square | do | 0.564 | 3.00 | 50,493 | ........ | 0.274 | A |
| 7 | 2½" square | Ordnance agency | 0.564 | 3.00 | 49,000 | 25,000 | 0.301 | A |
| 8 | 3" square | do | 0.564 | 3.00 | 48,000 | 24,000 | 0.285 | A |
| 9 | 4" × 3".35 | West Point foundry | 0.564 | 3.00 | 50,624 | ........ | 0.267 | A |
| 10 | 2¼" square | do | 0.564 | 3.00 | 50,420 | ........ | 0.28 | A |
| 11 | 2¼" square | do | 0.564 | 3.00 | 51,220 | ........ | 0.232 | A |
| 12 | 2½" square | Ordnance agency | 0.564 | 3.00 | 49,000 | 29,000 | 0.3127 | A |
| 13 | 2½" square | do | 0.564 | 3.00 | 49,000 | 30,000 | 0.3097 | A |
| 14 | 2¼" square | Ordnance agency | 0.564 | 3.00 | 48,377 | 27,015 | 0.2713 | B |
| 15 | 2¼" square | do | 0.564 | 3.00 | 48,500 | 26,000 | 0.299 | B |
| 16 | 4" × 3".35 | do | 0.564 | 3.00 | 45,600 | 23,000 | 0.174 | B |
| 17 | 4" × 3".35 | do | 0.564 | 3.00 | 44,500 | 22,000 | 0.266 | B |
| 18 | 4" × 3".35 | do | 0.564 | 3.00 | 49,500 | 21,000 | 0.296 | B |
| 19 | 4" × 3".35 | do | 0.564 | 3.00 | 49,500 | 25,000 | 0.268 | B |
| 20 | 2¼" square | West Point foundry | 0.564 | 3.00 | 50,626 | ........ | 0.327 | B |
| 21 | 5⅛" square | do | 0.564 | 3.00 | 48,236 | ........ | 0.22 | B |
| 22 | 5⅛" square | do | 0.564 | 3.00 | 51,220 | ........ | 0.232 | B |
| 23 | 2¼" square | do | 0.564 | 3.00 | 51,948 | ........ | 0.283 | B |
| 24 | 4" × 3".35 | do | 0.564 | 3.00 | 51,040 | ........ | 0.290 | B |
| 25 | 4" × 3".35 | do | 0.564 | 3.00 | 51,757 | ........ | 0.270 | B |
| 26 | 2½" square | Ordnance agency | 0.564 | 3.00 | 48,000 | 23,000 | 0.293 | B |
| 27 | 2½" square | do | 0.564 | 3.00 | 48,000 | 26,000 | 0.289 | B |

In order to determine to what extent these tests of specimens indicate the true physical properties of the bar itself, two bars of tube iron were obtained last January from the Ulster Iron Works for the purpose of having them broken in the machine at Watertown Arsenal. These bars of A and B quality, respectively, were 2.5 inches square in cross-sections, and 67 inches long. From the ends of each were taken the usual specimens, which were tested at the Ordnance agency, while the remainder of the bars were sent to Watertown Arsenal.

The following are the results obtained:

| | Watertown Arsenal. | Ordnance agency.* Mean of two results. |
|---|---|---|
| **A iron:** | | |
| Length between shoulders ........ inches | 21.876 | 3.00 |
| Cross-section ........ do | 2.5×2.13 | 0.570 |
| Area ........ square inches | 5.325 | 0.2547 |
| Tensile strength per square inch ........ pounds | 51,940.00 | 49,000.00 |
| Elastic limit per square inch ........ do | 20,000.00 | 29.500.00 |
| Extension per inch at rupture ........ inch | 0.273 | 0.3112 |
| **B iron:** | | |
| Length between shoulders ........ inches | 21.68 | 3.00 |
| Cross-section ........ do | 2".55×2".13 | 0.569 |
| Area ........ square inches | 5.4315 | 0.2552 |
| Tensile strength per square inch ........ pounds | 56,760.00 | 48,000.00 |
| Elastic limit per square inch ........ do | ........ | 24,500.00 |
| Extension per inch at rupture ........ inch | 0.2477 | 29.10 |

* Specimens 12, 13, 26, 27, preceding table.

It was anticipated that, in spite of the greater length between shoulders, the iron in the bar would exhibit a somewhat greater tensile strength per square inch than shown in the specimens, from the fact that on two sides of the bar the skin was not removed; the difference between the extensions in the two cases is also no greater than was expected from the difference in lengths. But there are three features shown in the above table which are inconsistent with the results which were anticipated.

1st. The elastic limit in the case of the A iron is very much lower in the bar than in the specimens.

2d. The two experiments disagree as to the comparative strength of the two grades of iron.

3d. The difference in strength between the B iron in the bar and in the specimens is much greater than the corresponding difference in the case of the A iron.

As regards the first of these:

The first permanent "set" of the A iron, as determined at Watertown Arsenal, was 0″.001, which becomes 0″.00012 when reduced to the length of the specimens (3″.00).

The last reading of the vernier used while testing the specimens is 0″.001; the first permanent set recorded is 0″.003. The permanent set commenced to increase rapidly with the bar after 27,000 pounds to the square inch, and with the specimens immediately after passing the recorded elastic limit.

It is probable, therefore, that the elastic limit as determined for the specimens was considerably too high, which would moderate this dissimilarity, as regards this property, between the iron in the bar and in the specimens.

As regards the two other discrepancies mentioned, in all probability they are explained by the fact noted in Colonel Laidley's report of the experiments at Watertown Arsenal: "At 268,600 pounds the packing of pump gave way, when the strain was taken off, and specimens stood twenty hours."

It seems, therefore, that the specimens ordinarily tested before accepting tube iron for use in gun constructions fairly represent the bars from which they are taken.

## APPENDIX 17.

### LONG-RANGE FIRING.

[*Being in continuation of Appendix 25, Report of 1880.*]

NATIONAL ARMORY,
*Springfield, Mass., October* 26, 1880.

SIR: I have the honor to inclose herewith the final reports of experimental firing made at this armory under my direction, by Captain Greer, Ordnance Department; also a report of firings made by Captain Michaelis, Ordnance Department, at the Frankford Arsenal, in verification of those by Captain Greer.

These experiments were mostly a continuation of those previously made and reported on by Captain Greer, having for their object the improvement of the range and accuracy of our service small arms. The conclusion to be derived from them is that the effectiveness of the rifle may be increased simply by increasing the weight of the bullet and without increasing the weight of the powder charge or changing in any respect the construction of the arm.

The objections to this change are the increased weight of ammunition to be carried by the soldier and the increased recoil. Whether these objections would outweigh the advantage to be derived can only be determined by the actual experience of the service.

It will be perceived that there is no falling off in accuracy of fire with the three-groove 500-grain bullet and 70 grains of powder, in the outside primed Frankford shell of service length; the objections heretofore found against the use of this cartridge shell appear to be removed by the heavier bullet.

Very respectfully, your obedient servant,

J. G. BENTON,
*Colonel of Ordnance, Commanding.*

CHIEF OF ORDNANCE, U. S. A.,
*Washington, D. C.*

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NATIONAL ARMORY,
*Springfield, Mass., October* 13, 1880.

SIR: I have the honor to submit herewith results of further trials with the 500-grain bullet prepared at the National Armory and described in my report of June 22, 1880, and also of a bullet weighing 505 grains having but 2 cannelures or grooves for the lubricant. The latter was suggested by Colonel Benton, Ordnance Department, for use with the solid-head copper shell made at the Frankford Arsenal, the powder space of which was of a less capacity by about 3 grains than that of the folded-head shell now in service.

The use of the solid-head shell with the service bullet of 405 grains was attended with a decided falling off in accuracy from that ordinarily obtained with the service folded head, and this was believed to be due to the greater compression of the powder in the smaller shell.

The 2-grooved bullet entering the shell to a less distance than the 3-grooved, the powder space was correspondingly increased. In order to give as long a bearing surface to this bullet as that of the 3-grooved it was left within 0″.001 of the caliber of the gun, 0″.45, some distance

in front of the shell, which was crimped down on the bullet in the usual manner. This bullet was fired at various ranges and gave excellent results so far as accuracy was concerned, but, owing to the closeness with which it fitted the bore, difficulty was found in closing the breech block after a few rounds. Another was then prepared which differed from the first only in being of slightly smaller diameter, 0''.004 in front of the shell. This one, known as No. 2, was fired with both solid and folded head shells, as it was desirable that any bullet adopted for service should work well with either. At the same time it was thought advisable to fire the 3-grooved bullet with both shells, with 70 grains powder in the service rifle, and also with 80 grains of powder in the long-chambered service and experimental rifles of 18-inch twist with both 3 and 6 grooves, by way of comparison.

When practicable, an equal number of targets of the various cartridges was made the same day, in order that all conditions should be the same.

Throughout the firing the lubricant employed was sperm oil and beeswax, except in 7 targets of the 2-grooved bullet at 1,000 and 10 targets at 500 yards, when the lubricant was Japan wax, that now used by the Ordnance Department, which was applied at Frankford Arsenal.

An examination of the summaries of firing at ranges of 1,000, 800, 500, and 300 yards and the accompanying abstract* shows that the best results were obtained with the long-chambered service rifle with 80 grains powder and 500-grain bullet, which is in accordance with the results given in the report previously referred to.

Omitting, however, all consideration of the long-chambered guns, it will be seen that the best results in the service rifle were obtained with the 500-grain bullet—3-grooved—and the solid-head shell. This rather surprising circumstance may be explained partly by the supposition that variations in the compression of the powder have less effect on the heavy bullet than on the light service bullet of 405 grains weight, and partly by the fact that the same marksman will frequently make consecutive targets with the same ammunition which differ widely. A single poor target may cause a bad average, particularly when the number of targets is comparatively limited. In these trials, however, the solid-head shell gave better results than the folded at all the ranges tried except at 500 yards, when they were about equal. The powder was a slow-burning one which had given excellent results when used in the 2.4-inch shell with 80-grain charges. It is possible that it was too slow for the 70-grain charge in the folded-head shell, and that the extra compression in the solid-head, which increased the velocity, improved the accuracy.

By comparing the records of both heavy bullets with that of the service it will be seen that somewhat better accuracy can always be expected from the former; and as this is accompanied with an increased range, it would seem desirable to give one or both of them a trial in service. The use of the 3-grooved bullet gives a more compact cartridge—the difference in length being about 0''.2 of an inch, and one in which the stability of the bullet is more fully assured. The shorter the cartridge the easier it will be to construct a magazine gun for its use.

Very respectfully, your obedient servant,

JOHN E. GREER,
*Captain of Ordnance, U. S. A.*

To the COMMANDING OFFICER, NATIONAL ARMORY.

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*The daily record is also submitted as showing conditions of wind, &c., under which the various cartridges were fired.

*Abstract of results of firing with Springfield bullets at ranges of 1,000, 800, 500, and 300 yards.*

| Rifle. | Powder. | | Bullet. | | | 1,000 yards. | | 800 yards. | | 500 yards. | | 300 yards. | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | Number of targets. | Mean deviations. | Number of targets. | Mean deviations. | Number of targets. | Mean deviations. | Number of targets. | Mean deviations. | |
| | *Grains.* | | *Grains.* | | | | *Inches.* | | *Inches.* | | *Inches.* | | *Inches.* | |
| Service ....... | 70 | Service ....... | 405 | .458 | Service,* $\frac{1}{16}$ tin ............ | 12 | 83.2 | 10 | 20.4 | 10 | 11.2 | 5 | 5.6 | Service shell. |
| Do ....... | 70 | Hazard, F. G | 505 | .4555 | Springfield, 2-grooved, No. 1, $\frac{1}{16}$ tin. | 10 | 20.1 | 20 | 14.4 | 39 | 7.8 | .... | ........ | Solid-head shell. |
| Do ....... | 70 | ....do ........ | 505 | .4555 | Springfield, 2-grooved, No. 2, $\frac{1}{16}$ tin. | 12 | 29.2 | .... | 19.1 | 10 | 7.9 | 5 | 3.8 | Do. |
| Do ....... | 70 | ....do ........ | 505 | .4555 | ......do ............ | 12 | 29.6 | .... | 20.5 | 10 | 11.3 | 5 | 4.7 | Folded-head shell. |
| Do ....... | 70 | ....do ........ | 505 | .4555 | Springfield, 2-grooved, No. 2, $\frac{1}{16}$ tin, Japan wax lubricant. | 4 | 28 | 10 | ........ | 8 | 9.2 | .... | ........ | Solid-head shell. |
| Do ....... | 70 | ....do ........ | 505 | .4555 | ......do ............ | 3 | 32.4 | 10 | ........ | 5 | 11.8 | .... | ........ | Folded-head shell. |
| Do ....... | 70 | ....do ........ | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 12 | 26.3 | 10 | 15.1 | 10 | 7.8 | 5 | 4.1 | Solid-head shell. |
| Do ....... | 70 | ....do ........ | 500 | .4555 | ......do ............ | 13 | 29.8 | 10 | 17.7 | 10 | 7.5 | 5 | 4.5 | Folded-head shell. |
| Service, long-chamber ....... | 80 | ....do ........ | 500 | .4555 | ......do ............ | 14 | 23.7 | 10 | 15.9 | 12 | 6.7 | 5 | 4 | Shell 2.4 inches long. |
| 18-inch twist, 3 grooves, long-chamber. | 80 | ....do ........ | 500 | .4555 | ......do ............ | 14 | 22.4 | 10 | 16.7 | 12 | 8.1 | 5 | 4.3 | Do. |
| 18-inch twist, 6 grooves, long-chamber. | 80 | ....do ........ | 500 | .4555 | ......do ............ | 14 | 25.1 | 10 | 17.3 | 12 | 7.1 | 5 | 4.4 | Do. |

* Service-cartridge made at Frankford arsenal.

*Summary of results of firing at 1,000 yards' range.*

| Rifle. | Powder. | | Bullet. | | | Number of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | | |
| | *Grains.* | | *Grains.* | | | | *Inches.* | |
| Service | 70 | Service | 405 | .458 | Service, $\frac{1}{16}$ tin | 12 | 33.2 | Service shell. |
| Do | 70 | Hazard, F. G. | 505 | .4555 | Springfield, 2-grooved, No. 1, $\frac{1}{16}$ tin | 10 | 20.1 | Solid-head shell. |
| Do | 70 | ....do | 505 | .4555 | ......do | 12 | 29.2 | Do. |
| Do | 70 | ....do | 505 | .4555 | ......do | 12 | 29.6 | Folded-head shell. |
| Do | 70 | ....do | 505 | .4555 | Springfield, 2-grooved, No. 2, $\frac{1}{16}$ tin, Japan wax lubricant. | 4 | 28 | Solid-head shell. |
| Do | 70 | ....do | 505 | .4555 | ......do | 3 | 32.4 | Folded-head shell. |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 12 | 26.8 | Solid-head shell. |
| Do | 70 | ....do | 500 | .4555 | ......do | 13 | 29.8 | Folded-head shell. |
| Service, long-chamber | 80 | ....do | 500 | .4555 | ......do | 14 | 23.7 | Shell 2.4 inches long. |
| Do | 80 | ....do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{17}$ tin | 5 | 26.1 | Do. |
| 18-inch twist, 3 grooves, long-chamber | 80 | ....do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 14 | 22.4 | Do. |
| Do | 80 | ....do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{17}$ tin | 5 | 28.3 | Do. |
| 18-inch twist, 6 grooves, long-chamber | 80 | ....do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 14 | 25.1 | Do. |
| Do | 80 | ....do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{17}$ tin | 4 | 32.8 | Do. |

*Summary of results of firing at 800 yards range.*

| Rifle. | Powder. | | Bullet. | | | Number of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | | |
| | *Grains.* | | *Grains.* | | | | *Inches.* | |
| Service | 70 | Service | 405 | .458 | Service | 10 | 20.4 | Service shell. |
| Do | 70 | Hazard, F. G. | 505 | .458 | Springfield, 2 grooved, No. 1, $\frac{1}{16}$ tin | 20 | 14.4 | Solid-head shell. |
| Do | 70 | ....do | 505 | .4555 | ......do | 10 | 19.1 | do. |
| Do | 70 | ....do | 505 | .4555 | ......do | 10 | 20.5 | Folded-head shell. |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3-grooved, No. 2, $\frac{1}{16}$ tin | 10 | 15.1 | Solid-head shell. |
| Do | 70 | ....do | 500 | .4555 | ......do | 10 | 17.7 | Folded-head shell. |
| Service, long-chamber | 80 | ....do | 500 | .4555 | ......do | 10 | 15.9 | Shell 2.4 inches long. |
| Do | 80 | ....do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 3 | 15.9 | do. |
| Do | 80 | ....do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{16}$ tin | 2 | 17.8 | do. |
| 18-inch twist, 3 grooves, long-chamber | 80 | ....do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 10 | 16.7 | do. |
| Do | 80 | ....do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 3 | 14.6 | do. |
| Do | 80 | ....do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{16}$ tin | 2 | 16.7 | do. |
| 18-inch twist, 6 grooves, long-chamber | 80 | ....do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 10 | 17.3 | do. |
| Do | 80 | ....do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 3 | 11 | do. |
| Do | 80 | ....do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{16}$ tin | 2 | 13.4 | do. |

*Summary of results of firing at 500 yards range.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | Number of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | *Grains.* | | *Grains.* | | | | *Inches.* | |
| Service | 70 | Service | 405 | .458 | Service, $\frac{1}{16}$ tin | 10 | 11.2 | Service shell. |
| Do | 70 | Hazard, F. G. | 405 | .458 | Service, one groove out, $\frac{1}{16}$ tin | 3 | 9.1 | |
| Do | 70 | ...do | 490 | .4555 | Springfield, 2-grooved, with 4 small grooves outside of shell, $\frac{1}{16}$ tin. | 5 | 9.2 | |
| Do | 70 | ...do | 505 | .4555 | Springfield, No. 1, 2-grooved, $\frac{1}{16}$ tin | 39 | 7.8 | Solid-head shell. |
| Do | 70 | ...do | 505 | .4555 | ......do | 10 | 7.9 | do. |
| Do | 70 | ...do | 505 | .4555 | ......do | 10 | 11.3 | Folded-head shell. |
| Do | 70 | ...do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 10 | 7.8 | Solid-head shell. |
| Do | 70 | ...do | 500 | .4555 | ......do | 10 | 7.5 | Folded-head shell. |
| Do | 70 | ...do | 505 | .4555 | Springfield, 2-grooved, No. 2, $\frac{1}{16}$ tin, lubricated with Japan wax. | 5 | 9.2 | Solid-head shell. |
| Do | 70 | ...do | 505 | .4555 | ......do | 5 | 11.8 | Folded head shell. |
| Service, long-chamber | 75 | Dupont | 500 | .458 | Frankford, 3-grooved, $\frac{1}{16}$ tin | 4 | 9.3 | Shell 2.4 inches long. |
| Do | 80 | Hazard, F. G. | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 12 | 6.7 | do. |
| Do | 90 | ...do | 550 | .458 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 1 | 10.5 | do. |
| 18-inch twist, 3 grooves, long-chamber | 80 | Oriental | 500 | .458 | Frankford, 3-grooved, $\frac{1}{16}$ tin | 4 | 13.4 | do. |
| Do | 80 | Hazard, F. G. | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 12 | 8.1 | do. |
| Do | 90 | ...do | 550 | .458 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 1 | 7.3 | do. |
| 18 inch twist, 6 grooves, long-chamber | 80 | ...do | 500 | .446 | Patched, $\frac{1}{16}$ tin | 3 | 12.6 | Bullet, when patched, cal. 453 2.4 inches shell. |
| Do | 80 | ...do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 12 | 7.1 | Shell 2.4 inches long. |
| Do | 90 | ...do | 550 | .458 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 2 | 8.9 | do. |
| Long-range, long-chamber, $19\frac{5}{8}$-inch twist, 6 grooves. | 70 | ...do | 505 | .4555 | Springfield, 2-grooved, No. 1, $\frac{1}{16}$ tin | 5 | 10.2 | Solid-head shell, service length. |
| Long-range, long-chamber, $19\frac{5}{8}$-inch twist, 6 grooves. | 80 | ...do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{16}$ tin | 2 | 9.2 | Shell 2.4 inches long. |
| Do | 80 | ...do | 500 | .446 | Patched, $\frac{1}{16}$ tin | 3 | 8.8 | Bullet, when patched, cal. 453; 2.4 inches shell. |
| Do | 80 | ...do | 500 | .446 | ......do | 4 | 9.1 | Bullet, when patched, cal. 453; service-length shell. |

*Summary of results of firing at 300 yards range.*

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | | |
| | *Grs.* | | *Grs.* | | | | *Inches.* | |
| Service | 70 | Service | 405 | .458 | Service | 5 | 5.6 | Service shell. |
| Do | 70 | Hazard, F. G | 505 | .4555 | Springfield, 2-grooved, No. 2, $\frac{1}{16}$ tin | 5 | 3.8 | Solid-head shell. |
| Do | 70 | do | 505 | .4555 | do | 5 | 4.7 | Folded-head shell. |
| Do | 70 | do | 500 | .4555 | Springfield, 3-grooved, No. 2, $\frac{1}{16}$ tin | 5 | 4.1 | Solid-head shell. |
| Do | 70 | do | 500 | .4555 | do | 5 | 4.5 | Folded-head shell. |
| Service, long-chamber | 80 | do | 500 | .4555 | do | 5 | 4.0 | Shell 2.4 inches long. |
| Do | 80 | do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{12}$ tin | 1 | 5.0 | do. |
| Do | 80 | do | | .458 | Frankford, 3-grooved, $\frac{1}{12}$ tin | 1 | 7.2 | do. |
| Do | 80 | do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{17}$ tin | 1 | 6.2 | do. |
| Do | 80 | Oriental | 500 | .458 | do | 1 | 9.4 | do. |
| Do | 80 | Dupont | 500 | .458 | Frankford, 3-grooved, $\frac{1}{13}$ tin | 2 | 6.8 | do. |
| Do | 75 | do | 500 | .458 | do | 1 | 3.4 | do. |
| 18-inch twist, 3 grooves; long-chamber | 80 | Hazard, F. G | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 5 | 4.3 | do. |
| Do | 80 | do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{12}$ tin | 1 | 4.5 | do. |
| Do | 80 | do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{13}$ tin | 1 | 5.2 | do. |
| Do | 80 | do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{17}$ tin | 1 | 6.1 | do. |
| Do | 80 | Oriental | 500 | .458 | do | 1 | 5.7 | do. |
| Do | 80 | Dupont | 500 | .458 | Frankford, 3-grooved, $\frac{1}{13}$ tin | 2 | 6.5 | do. |
| Do | 75 | do | 500 | .458 | do | 1 | 4.8 | do. |
| 18-inch twist, 6 grooves; long-chamber | 80 | Hazard, F. G | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin | 5 | 4.4 | do. |
| Do | 80 | do | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{12}$ tin | 1 | 6.0 | do. |
| Do | 80 | do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{17}$ tin | 2 | 4.1 | do. |
| Do | 80 | Oriental | 500 | .458 | do | 1 | 11.3 | do. |
| Do | 80 | do | 500 | .458 | Frankford, 3-grooved, $\frac{1}{13}$ tin | 1 | 5.7 | do. |
| Do | 80 | Dupont | 500 | .458 | do | 1 | 5.9 | do. |
| Do | 75 | do | 500 | .458 | do | 1 | 5.3 | do. |

*1,000 yards range.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| | *Grs.* | | *Grs.* | | | | | | |
| July 28, 1880. Service, long-chamber. | 80 | Hazard, F. G.. | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 6.3 | 17.2 | 18.3 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................ | 2 | 15.2 | 13.1 | 20 |
| | | [Calm.] | | | | Mean. | 10.7 | 15.1 | 19.1 |
| Aug. 5, 1880. Service........ | 70 | Hazard, F. G.. | 505 | .4555 | Springfield, 2-grooved, No. 1, 1/16 tin, solid-head shell. | 1 | 9.6 | 15.1 | 17.9 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do................ | 2 | 18.7 | 13.2 | 22.9 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do................ | 3 | 19.9 | 17.2 | 26.3 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do................ | 4 | 8.8 | 17.6 | 19.3 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do................ | 5 | 10.7 | 10.8 | 15.2 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do................ | 6 | 12.9 | 23 | 26.4 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do................ | 7 | 18.4 | 11 | 21.4 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do................ | 8 | 10.5 | 12 | 16 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do................ | 9 | 14.3 | 7.9 | 16.4 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do................ | 10 | 14.5 | 12.6 | 19.2 |
| | | [Calm.] | | | | Mean. | 13.8 | 14. | 20.1 |
| Sept. 2, 1880. Service, long-chamber. | 80 | Hazard, F. G.. | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 14.1 | 12.7 | 19 |
| Do......... | 80 | ....do ......... | 500 | .458 | Frankford, 3-grooved, 1/17 tin. | 1 | 13.1 | 20 | 23.9 |
| Do......... | 80 | ....do ......... | 500 | .458 | ......do................ | 2 | 14.4 | 21.9 | 26.2 |
| | | | | | | Mean. | 13.7 | 20.9 | 25 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 18.6 | 14.8 | 23.6 |
| Do......... | 80 | ....do ......... | 500 | .458 | Frankford, 3-grooved, 1/17 tin. | 1 | 14.9 | 15.5 | 21.5 |
| Do......... | 80 | ....do ......... | 500 | .458 | ......do................ | 2 | 13.6 | 24.2 | 27.8 |
| | | | | | | Mean. | 14.2 | 19.8 | 24.6 |
| 18 inch twist, 6 grooves, long-chamber. | 80 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 17 | 18.3 | 25 |
| Do......... | 80 | ....do ......... | 500 | .458 | Frankford, 3-grooved, 1/17 tin. | 1 | 21.7 | 28 | 35.4 |
| Do......... | 80 | ....do ......... | 500 | .458 | ......do................ | 2 | 15.7 | 30.6 | 34.4 |
| | | [Heavy wind | from | right | and front.] | Mean. | 18.7 | 29.3 | 34.9 |
| Sept. 3, 1880. Service, long-chamber. | 80 | Hazard, F. G.. | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 26.8 | 14.6 | 30.5 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................ | 2 | 10.3 | 15 | 18.2 |
| | | | | | | Mean. | 18.5 | 14.8 | 24.3 |
| Do......... | 80 | ....do ......... | 500 | .458 | Frankford, 3-grooved, 1/17 tin. | 1 | 18.6 | 27.2 | 30.4 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 11.8 | 12 | 16.5 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................ | 2 | 18.8 | 14.8 | 23.9 |
| | | | | | | Mean. | 15 | 13.4 | 20.2 |
| Do......... | 80 | ....do ......... | 500 | .458 | Frankford, 3-grooved, 1/17 tin. | 1 | 15.3 | 23.7 | 28.2 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | ....do......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 14.9 | 12.5 | 19.4 |
| Do......... | 80 | ....do......... | 500 | .4555 | ......do................ | 2 | 18 | 15 | 23.4 |
| | | | | | | Mean. | 16.4 | 13.7 | 21.4 |
| Do ........ | 80 | ....do ......... | 500 | .458 | Frankford, 3-grooved, 1/17 tin. | 1 | 31.6 | 13.3 | 34.3 |
| | | [Heavy wind | from | right | and front.] | | | | |

1,000 *yards range*—Continued.

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| | *Grs.* | | *Grs.* | | | | | | |
| Sept. 21, 1880. Service, long-chamber. | 80 | Hazard, F. G. . | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 18.1 | 15.2 | 23.6 |
| Do.......... | 80 | ....do......... | 500 | .4555 | ......do................. | 2 | 22.4 | 18.5 | 29.1 |
| | | | | | | Mean . | 20.2 | 16.8 | 26.3 |
| Service ........ | 70 | ....do......... | 505 | .4555 | Springfield, 2-grooved, No. 2, 1/16 tin, solid-head shell. | 1 | 9.5 | 19.3 | 21.5 |
| Do.......... | 70 | ....do......... | 505 | .4555 | ......do................. | 2 | 14.2 | 21 | 25.4 |
| Do.......... | 70 | ....do......... | 505 | .4555 | ......do ................ | 3 | 20.5 | 24.5 | 31.9 |
| | | | | | | Mean . | 14.7 | 21.6 | 26.3 |
| Do.......... | 70 | ....do......... | 505 | .4555 | Springfield, 2-grooved, No. 2, 1/16 tin, folded-head shell. | 1 | 12.8 | 22.2 | 25.6 |
| Do.......... | 70 | ....do......... | 505 | .4555 | ......do................. | 2 | 8.6 | 14.4 | 16.8 |
| Do.......... | 70 | ....do......... | 505 | .4555 | ......do................. | 3 | 10.2 | 26 | 27.9 |
| | | | | | | Mean . | 10.5 | 20.9 | 23.4 |
| Do.......... | 70 | ....do......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin,* solid-head shell. | 1 | 16.2 | 29.8 | 33.9 |
| Do.......... | 70 | ....do......... | 500 | .4555 | ......do................. | 2 | 16.2 | 11 | 19.6 |
| Do.......... | 70 | ....do......... | 500 | .4555 | ......do................. | 3 | 10.6 | 18.2 | 21.1 |
| | | | | | | Mean | 14.3 | 19.7 | 24.9 |
| Do.......... | 70 | ....do......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin, folded-head shell. | 1 | 30.9 | 20.5 | 37.1 |
| Do.......... | 70 | ....do......... | 500 | .4555 | ......do................. | 2 | 7.7 | 16.9 | 18.6 |
| Do.......... | 70 | ....do......... | 500 | .4555 | ......do................. | 3 | 10.1 | 14.8 | 17.9 |
| [Strong wind from right and front.] | | | | | | Mean . | 16.2 | 17.4 | 24.5 |
| Sept. 22, 1880. Service, long-chamber. | 80 | ....do......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 6.3 | 17.5 | 18.6 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | ....do......... | 500 | .4555 | ......do................. | 1 | 18.5 | 21.4 | 28.3 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | ....do......... | 500 | .4555 | ......do................. | 1 | 15.2 | 19.6 | 24.8 |
| [Strong wind from right.] | | | | | | | | | |
| Sept. 25, 1880. Service ........ | 70 | ....do......... | 505 | .4555 | Springfield, 2-grooved, No. 2. 1/16 tin, solid-head shell. | 1 | 12.5 | 18.4 | 22.2 |
| Do.......... | 70 | ....do......... | 505 | .4555 | ......do................. | 2 | 8.1 | 30.8 | 31.8 |
| Do.......... | 70 | ....do......... | 505 | .4555 | ......do................. | 3 | 19.9 | 18.8 | 27.4 |
| | | | | | | Mean . | 13.5 | 22.6 | 27.1 |
| Do.......... | 70 | ....do......... | 505 | .4555 | Springfield, 2-grooved, No. 2, 1/16 tin, folded-head shell. | 1 | 11.9 | 34.9 | 36.1 |
| Do.......... | 70 | ....do......... | 505 | .4555 | ......do................. | 2 | 15.6 | 28.2 | 32.2 |
| | | | | | | Mean . | 13.7 | 31.5 | 34.5 |
| Do.......... | 70 | ....do......... | 500 | .4555 | ......do................. | 1 | 19.5 | 20 | 27.9 |
| Do.......... | 70 | ....do......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin, folded-head shell. | 1 | 17.6 | 22.8 | 28.8 |
| Do.......... | 70 | ....do......... | 500 | .4555 | ......do................. | 2 | 19.9 | 22.8 | 30.3 |
| Do.......... | 70 | ....do......... | 500 | .4555 | ......do................. | 3 | 16.7 | 23.1 | 28.5 |
| [Strong wind from right and rear.] | | | | | | Mean . | 18.1 | 22.9 | 29.2 |

1,000 *yards range*—Continued.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M.H. | Deviations. M.V. | Deviations. M.A. |
|---|---|---|---|---|---|---|---|---|---|
| Oct. 2, 1880. | *Grs.* | | *Grs.* | | | | | | |
| Service ........ | 70 | Service ....... | 405 | .458 | Service .................. | 1 | 23.9 | 18.4 | 30.2 |
| Do ........ | 70 | ....do ......... | 405 | .458 | ......do .................. | 2 | 21.7 | 27.1 | 34.7 |
| | | | | | | Mean. | 22.8 | 22.7 | 32.5 |
| Do ........ | 70 | Hazard, F. G .. | 505 | .4555 | Springfield, 2-grooved, No. 2, $\frac{1}{16}$ tin, solid-head shell. | 1 | 14.8 | 32.8 | 36 |
| Do ........ | 70 | ....do ......... | 505 | .4555 | ......do .................. | 2 | 10.5 | 32.8 | 34.4 |
| | | | | | | Mean. | 12.6 | 32.8 | 35.2 |
| Do ........ | 70 | ....do ......... | 505 | .4555 | Springfield, 2-grooved, No. 2, $\frac{1}{16}$ tin, folded-head shell. | 1 | 19.8 | 36.5 | 41.5 |
| Do ........ | 70 | ....do ......... | 505 | .4555 | ......do .................. | 2 | 12.6 | 18.8 | 22.6 |
| | | | | | | Mean. | 16.2 | 27.6 | 32 |
| Do ........ | 70 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin, solid-head shell. | 1 | 19.9 | 15.3 | 25.1 |
| Do ........ | 70 | ....do ......... | 500 | .4555 | ......do .................. | 2 | 13.3 | 18.7 | 22.9 |
| | | | | | | Mean. | 16.6 | 17 | 24 |
| Do ........ | 70 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin, folded-head shell. | 1 | 12.8 | 30.4 | 33 |
| Do ........ | 70 | ....do ......... | 500 | .4555 | ......do .................. | 2 | 17.5 | 16.7 | 24.2 |
| [Stiff breeze from right and front.] | | | | | | Mean. | 15.1 | 23.5 | 28.6 |
| Oct. 5, 1880. | | | | | | | | | |
| Service ........ | 70 | Service ....... | 405 | .458 | Service .................. | 1 | 28 | 25.3 | 37.7 |
| Do ........ | 70 | ....do ......... | 405 | .458 | ......do .................. | 2 | 20.8 | 19.6 | 28.6 |
| Do ........ | 70 | ....do ......... | 405 | .458 | ......do .................. | 3 | 29.2 | 22.1 | 36.5 |
| | | | | | | Mean. | 26 | 22.3 | 34.3 |
| Do ........ | 70 | Hazard, F. G .. | 505 | .4555 | Springfield, 2-grooved, No. 2, $\frac{1}{16}$ tin, solid-head shell. | 1 | 14.3 | 21.3 | 25.7 |
| Do ........ | 70 | ....do ......... | 505 | .4555 | ......do .................. | 2 | 16.4 | 39.9 | 43.1 |
| | | | | | | Mean. | 15.3 | 30.6 | 34.4 |
| Do ........ | 70 | ....do ......... | 505 | .4555 | Springfield, 2-grooved, No. 2, $\frac{1}{16}$ tin, folded-head shell. | 1 | 38.8 | 20. | 43.7 |
| Do ........ | 70 | ....do ......... | 505 | .4555 | ......do .................. | 2 | 5.8 | 17.5 | 18.4 |
| Do ........ | 70 | ....do ......... | 505 | .4555 | ......do .................. | 3 | 15.9 | 26.4 | 30.8 |
| | | | | | | Mean. | 20.1 | 21.3 | 30.7 |
| Do ........ | 70 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin, solid-head shell. | 1 | 14.8 | 24 | 28.2 |
| Do ........ | 70 | ....do ......... | 500 | .4555 | ......do .................. | 2 | 19.8 | 15.9 | 25.4 |
| Do ........ | 70 | ....do ......... | 500 | .4555 | ......do .................. | 3 | 13.9 | 19.8 | 24.2 |
| | | | | | | Mean. | 16.2 | 19.9 | 25.9 |
| Do ........ | 70 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, $\frac{1}{16}$ tin, folded-head shell. | 1 | 20.8 | 22.3 | 30.5 |
| Do ........ | 70 | ....do ......... | 500 | .4555 | ......do .................. | 2 | 20.2 | 21 | 29.1 |
| Do ........ | 70 | ....do ......... | 500 | .4555 | ......do .................. | 3 | 15.6 | 33.6 | 37.1 |
| [Fresh breeze from the right and front.] | | | | | | Mean. | 18.9 | 25.6 | 32.2 |
| Oct. 8, 1880. | | | | | | | | | |
| Service ........ | 70 | Service ....... | 405 | .458 | Service, $\frac{1}{16}$ tin .......... | 1 | 12.8 | 32.4 | 34.8 |
| Do ........ | 70 | ....do ......... | 405 | .458 | ......do .................. | 2 | 16.1 | 28.9 | 33.1 |
| | | | | | | Mean. | 14.4 | 30.6 | 33.9 |

1,000 *yards range*—Continued.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| Oct. 8, 1880. | *Grs.* | | *Grs.* | | | | | | |
| Service ........ | 70 | Hazard, F. G.. | 505 | .4555 | Springfield, 2-grooved, No. 2, 1/16 tin, solid-head shell, lubricated with Japan wax. | 1 | 21.7 | 17 | 27.6 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do ................ | 2 | 15.4 | 20.6 | 25.7 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do ................ | 3 | 25.2 | 23.8 | 34.7 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do ................ | 4 | 16.4 | 17.7 | 24.1 |
| | | | | | | Mean. | 19.7 | 19.8 | 28.0 |
| Do......... | 70 | ....do ......... | 505 | .4555 | Springfield, 2-grooved, No. 2, 1/16 tin, folded-head shell, lubricated with Japan wax. | 1 | 20.5 | 28.4 | 35 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do ................ | 2 | 13.8 | 30.3 | 33.3 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do ................ | 3 | 19.7 | 21 | 28.8 |
| | | | | | | Mean. | 18 | 26.6 | 32.4 |
| Do......... | 70 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin, solid-head shell. | 1 | 10.3 | 22.4 | 24.7 |
| Oct. 9, 1880. | | Calm. | | | | | | | |
| Service ........ | 70 | Service ....... | 405 | .458 | Service, 1/16 tin .......... | 1 | 22.7 | 31.1 | 38.5 |
| Do......... | 70 | ....do ......... | 405 | .458 | ......do ................ | 2 | 14.8 | 24.6 | 28.7 |
| | | | | | | Mean. | 18.7 | 27.8 | 33.6 |
| Service, long-chamber. | 80 | Hazard, F. G.. | 500 | .458 | Frankford, 3-grooved, 1/16 tin. | 1 | 12.8 | 24.1 | 27.3 |
| Do......... | 80 | ....do ......... | 500 | .458 | ......do ................ | 2 | 5.2 | 22 | 22.6 |
| | | | | | | Mean. | 9 | 23.0 | 24.9 |
| Do......... | 80 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 10.5 | 29.9 | 31.7 |
| Do......... | 80 | ... do ......... | 500 | .4555 | ......do ................ | 2 | 17.3 | 16.4 | 23.8 |
| | | | | | | Mean. | 13.9 | 23.1 | 27.7 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | ... do ......... | 500 | .458 | Frankford, 3-grooved, 1/16 tin. | 1 | 12.8 | 32.8 | 35.2 |
| Do......... | 80 | ....do ......... | 500 | .458 | ......do ................ | 2 | 18.8 | 21.8 | 28.8 |
| | | | | | | Mean. | 15.8 | 27.3 | 32 |
| Do......... | 80 | ... do ......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 13.4 | 14.5 | 19.7 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do ................ | 2 | 8.9 | 14.2 | 16.7 |
| | | | | | | Mean. | 11.1 | 14.3 | 18.2 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | ....do ......... | 500 | .458 | Frankford, 3-grooved, 1/16 tin. | 1 | 14.8 | 22.7 | 27.1 |
| Do......... | 80 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 12.8 | 13.6 | 18.7 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do ................ | 2 | 13.1 | 32.5 | 35 |
| [Fresh breeze from the front.] | | | | | | Mean. | 12.9 | 23.0 | 26.8 |
| Oct. 11, 1880. | | | | | | | | | |
| Service ........ | 70 | Service ....... | 405 | .458 | Service ................ | 1 | 11.8 | 19 | 22.4 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | Hazard, F. G.. | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 15.9 | 12.5 | 20.2 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do ................ | 2 | 11.6 | 15.6 | 19.5 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do ................ | 3 | 12 | 19.1 | 22.6 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do ................ | 4 | 16.3 | 11.3 | 19.8 |
| | | | | | | Mean. | 13.9 | 14.6 | 20.5 |

1,000 *yards range*—Continued.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| | *Grs.* | | *Grs.* | | | | | | |
| Oct. 11, 1880. 18-inch twist, 6 grooves, long-chamber. | 80 | Hazard, F. G.. | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 13 | 23.4 | 26.8 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do ............ ...... | 2 | 16.3 | 16.5 | 23.2 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do .... ............ | 3 | 10.1 | 12.1 | 15.8 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do ............ .... | 4 | 19.7 | 17.2 | 26.1 |
| [Stiff bre | eze | from front.] | | | | Mean . | 14.8 | 17.3 | 22.9 |
| Oct. 12, 1880. Service ........ | 70 | ....do ......... | 505 | .4555 | Springfield, 2-grooved, No. 2, 1/16 tin, solid-head shell. | 1 | 6.6 | 18.4 | 19.5 |
| Do......... | 70 | ....do ......... | 505 | .4555 | ......do................. | 2 | 12.4 | 29.2 | 31.7 |
| | | | | | | Mean . | 9.5 | 23.8 | 25.6 |
| Service, long-chamber. | 80 | ....do ......... | 500 | .4555 | Springfield, 3-grooved, 1/16 tin. | 1 | 14.3 | 13.2 | 19.5 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 2 | 14 | 21.8 | 25.9 |
| | | | | | | Mean . | 14.1 | 17.5 | 22.7 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | ....do ......... | 500 | .4555 | ......do................. | 1 | 11.3 | 14.3 | 18.2 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 2 | 15.2 | 9.1 | 17.7 |
| | | | | | | Mean . | 13.2 | 11.7 | 17.9 |
| Oct. 12, 1880. 18-inch twist, 6 grooves, long-chamber. | 80 | ....do ......... | 500 | .4555 | ......do................. | 1 | 12.1 | 15.7 | 19.8 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 2 | 21.8 | 19.6 | 29.3 |
| Very stro | ng | wind from the | right. | | | Mean . | 16.9 | 17.6 | 24.5 |
| Oct. 13 1880. Service ........ | 70 | Service ....... | 405 | .458 | Service, 1/16 tin.......... | 1 | 25.7 | 18.3 | 31.5 |
| Do......... | 70 | ....do ......... | 405 | .458 | ......do................. | 2 | 37.3 | 19.4 | 42 |
| | | | | | | Mean . | 31.5 | 18.8 | 36.7 |
| Do......... | 70 | Hazard, F. G.. | 505 | .4555 | Springfield, 2 grooved, No. 2, 1/16 tin, folded-head shell. | 1 | 20.8 | 14 | 25.1 |
| Do......... | 70 | ....do ...... ... | 505 | .4555 | ......do................. | 2 | 12.9 | 32.1 | 34.6 |
| | | | | | | Mean . | 16.8 | 23 | 29.8 |
| Do......... | 70 | ....do ......... | 500 | .4555 | Springfield, 3 grooved, 1/16 tin, solid-head shell. | 1 | 18.5 | 25.6 | 31.6 |
| Do......... | 70 | ....do ......... | 500 | .4555 | ......do................. | 2 | 22.4 | 21.4 | 31 |
| | | | | | | Mean . | 20.4 | 23.5 | 31.3 |
| Do......... | 70 | ....do ......... | 500 | .4555 | Springfield, 3 grooved, 1/16 tin, folded-head shell. | 1 | 10.3 | 27.3 | 29.2 |
| Do......... | 70 | ....do ......... | 500 | .4555 | ......do................. | 2 | 26.3 | 32.8 | 42 |
| | | | | | | Mean . | 18.3 | 30 | 35.6 |
| Service, long-chamber. | 70 | ....do ......... | 500 | .4555 | Springfield, 3 grooved, 1/16 tin. | 1 | 9.9 | 20.1 | 22.4 |
| Do......... | 70 | ....do ......... | 500 | .4555 | ...... do................. | 2 | 28.4 | 14.9 | 32.1 |
| | | | | | | Mean . | 19.1 | 17.5 | 27.2 |

1,000 *yards range*—Continued.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| Oct. 13, 1880. | *Grs.* | | *Grs.* | | | | | | |
| 18-inch twist, 3 grooves, long-chamber. | 80 | Hazard, F. G. | 500 | .4555 | Springfield, 3 grooved, 1/16 tin. | 1 | 28.8 | 17.3 | 33.6 |
| Do | 80 | do | 500 | .4555 | do | 2 | 26 | 19.9 | 32.7 |
| | | | | | | Mean | 27.4 | 18.6 | 33.1 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | do | 500 | .4555 | do | 1 | 17 | 19.8 | 26.1 |
| Do | 80 | do | 500 | .4555 | do | 2 | 30.4 | 22.7 | 37.9 |
| Wind strong and gusty from right and front. | | | | | | Mean | 23.7 | 21.2 | 32 |

800 *yards range*.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| Service | 70 | Hazard, F. G. | 505 | .458 | Springfield, 2 grooved, No. 1, 1/16 tin. | 1 | 12.8 | 8.5 | 15.4 |
| Do | 70 | do | 505 | .458 | do | 2 | 11.9 | 5.8 | 13.2 |
| Do | 70 | do | 505 | .458 | do | 3 | 9.9 | 9.9 | 14 |
| Do | 70 | do | 505 | .458 | do | 4 | 12.2 | 12.5 | 17.5 |
| Do | 70 | do | 505 | .458 | do | 5 | 11.4 | 6.6 | 13.2 |
| | | | | | | Mean | 11.6 | 8.7 | 14.7 |
| July 31, 1880. | | | | | | | | | |
| Service | 70 | do | 505 | .458 | do | 1 | 10.4 | 9.8 | 14.3 |
| Do | 70 | do | 505 | .458 | do | 2 | 9.5 | 7.1 | 11.9 |
| Do | 70 | do | 505 | .458 | do | 3 | 8.1 | 9.9 | 12.8 |
| Do | 70 | do | 505 | .458 | do | 4 | 13.7 | 13.6 | 19.3 |
| Do | 70 | do | 505 | .458 | do | 5 | 11.7 | 10.6 | 15.8 |
| Do | 70 | do | 505 | .458 | do | 6 | 10.2 | 12 | 15.8 |
| Do | 70 | do | 505 | .458 | do | 7 | 9.9 | 10 | 14.1 |
| Do | 70 | do | 505 | .458 | do | 8 | 8.3 | 11.5 | 14.2 |
| Do | 70 | do | 505 | .458 | do | 9 | 12.6 | 10 | 16.1 |
| Do | 70 | do | 505 | .458 | do | 10 | 10.2 | 13.2 | 16.7 |
| | | | | | | Mean | 14.1 | 10.8 | 15.1 |
| Service, long-chamber. | 80 | do | 500 | .4555 | Springfield, 3 grooved, 1/16 tin. | 1 | 9 | 10.5 | 13.8 |
| Do | 80 | do | 500 | .4555 | do | 2 | 13.4 | 12.8 | 18.5 |
| | | | | | | Mean | 11.2 | 11.6 | 16.1 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | do | 500 | .4555 | do | 1 | 8.8 | 10.8 | 13.9 |
| Do | 80 | do | 500 | .4555 | do | 2 | 6.3 | 13.9 | 15.2 |
| | | | | | | Mean | 7.5 | 12.3 | 14.5 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | do | 500 | .4555 | do | 1 | 9.2 | 12 | 15.1 |
| Do | 80 | do | 500 | .4555 | do | 2 | 10.3 | 10.8 | 14.9 |
| | | | | | | Mean | 9.7 | 11.4 | 15 |
| Aug. 9, 1880. | | | | | | | | | |
| Service | 70 | do | 505 | .458 | Springfield, 2 grooved, No. 1, 1/16 tin. | 1 | 7.4 | 6.7 | 10 |
| Do | 70 | do | 505 | .458 | do | 2 | 10.6 | 8.6 | 13.7 |
| Do | 70 | do | 505 | .458 | do | 3 | 12.3 | 7.4 | 14.4 |
| Do | 70 | do | 505 | .458 | do | 4 | 6.7 | 13.2 | 14.8 |
| Do | 70 | do | 505 | .458 | do | 5 | 8 | 8 | 11.3 |
| | | | | | | Mean | 9 | 8.8 | 12.8 |

800 *yards range*—Continued.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| | *Grs.* | | *Grs.* | | | | | | |
| Aug. 31, 1880. Service, long-chamber. | 80 | Hazard, F. G. | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{32}$ tin. | 1 | 7.4 | 10.4 | 12.8 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 7 | 11.7 | 13.6 |
| Do | 80 | ....do | 500 | .4555 | ......do | 3 | 5.8 | 22.5 | 23.2 |
| Do | 80 | ....do | 500 | .4455 | ......do | 4 | 9.4 | 11.9 | 15.2 |
| | | | | | | Mean. | 7.4 | 14.1 | 16.2 |
| Aug. 31, 1880. Service, long-chamber. | 80 | ....do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{32}$ tin. | 1 | 7.5 | 13.2 | 15.2 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 12.1 | 9.9 | 15.6 |
| Do | 80 | ....do | 500 | .4555 | ......do | 3 | 8.3 | 14.8 | 17 |
| | | | | | | Mean. | 9.3 | 12.6 | 15.9 |
| Do | 80 | ....do | 500 | .458 | Frankford, 3 grooved, $\frac{1}{32}$ tin. | 1 | 11 | 7.5 | 13.3 |
| Do | 80 | ....do | 500 | .458 | ......do | 2 | 12.9 | 18.2 | 22.3 |
| | | | | | | Mean. | 11.9 | 12.8 | 17.8 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | ....do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{32}$ tin. | 1 | 16 | 9.3 | 18.5 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 19.1 | 13.2 | 23.2 |
| Do | 80 | ....do | 500 | .4555 | ......do | 3 | 5 | 9.8 | 11 |
| Do | 80 | ....do | 500 | .4555 | ......do | 4 | 9.7 | 15.6 | 18.4 |
| | | | | | | Mean. | 12.4 | 11.9 | 17.8 |
| Do | 80 | ....do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{32}$ tin. | 1 | 9.2 | 12.8 | 15.8 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 6.2 | 10.6 | 12.3 |
| Do | 80 | ....do | 500 | .4555 | ......do | 3 | 10.2 | 12.1 | 15.8 |
| | | | | | | Mean. | 8.5 | 11.8 | 15.6 |
| Do | 80 | ....do | 500 | .458 | Frankford, 3 grooved, $\frac{1}{32}$ tin. | 1 | 7.9 | 14.9 | 16.9 |
| Do | 80 | ....do | 500 | .458 | ......do | 2 | 8.6 | 14.1 | 16.5 |
| | | | | | | Mean. | 8.2 | 14.5 | 16.7 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | ....do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{32}$ tin. | 1 | 14.1 | 11.9 | 18.4 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 8.8 | 13 | 15.7 |
| Do | 80 | ....do | 500 | .4555 | ......do | 3 | 11.1 | 9.4 | 14.5 |
| Do | 80 | ....do | 500 | .4555 | ......do | 4 | 10.2 | 10.6 | 14.7 |
| | | | | | | Mean. | 11.0 | 11.2 | 15.8 |
| Do | 80 | ....do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{32}$ tin. | 1 | 4.8 | 7 | 8.5 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 8.2 | 8.7 | 12 |
| Do | 80 | ....do | 500 | .4555 | ......do | 3 | 9.6 | 8.4 | 12.7 |
| | | | | | | Mean. | 7.5 | 8 | 11 |
| Do | 80 | ....do | 500 | .458 | Frankford, 3 grooved, $\frac{1}{32}$ tin. | 1 | 12.2 | 6.9 | 14 |
| Do | 80 | ....do | 500 | .458 | ......do | 2 | 6.9 | 10.8 | 12.8 |
| | | | | | | Mean. | 9.5 | 8.8 | 13.4 |
| Sept. 28, 1880. Service | 70 | ....do | 500 | .4555 | Springfield, 2 grooved, No. 2, $\frac{1}{32}$ tin, solid-head shell. | 1 | 6 | 15.4 | 16.5 |

800 *yards range*—Continued.

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | M.H. | M.V. | M.A. |
| | Grs. | | Grs. | | | | | | |
| Sept. 28, 1880. Service | 70 | Hazard, F. G. | 500 | .4555 | Springfield, 2 grooved, No. 2, $\frac{1}{16}$ tin, solid-head shell. | 2 | 13.4 | 17.7 | 22.2 |
| | | | | | | Mean. | 7 | 16.5 | 19.3 |
| Do | 70 | do | 500 | .4555 | Springfield, 2 grooved, No. 2, $\frac{1}{16}$ tin, folded-head shell. | 1 | 11.7 | 18.9 | 22.2 |
| Sept. 29, 1880. Service | 70 | do | 500 | .4555 | Service, $\frac{1}{16}$ tin | 1 | 15.1 | 15.3 | 21.5 |
| Do | 70 | do | 500 | .4555 | do | 2 | 11.6 | 12.2 | 16.8 |
| Do | 70 | do | 500 | .4555 | do | 3 | 12.9 | 10.2 | 16.4 |
| Do | 70 | do | 500 | .4555 | do | 4 | 21.9 | 17.9 | 28.3 |
| Do | 70 | do | 500 | .4555 | do | 5 | 8.5 | 13.2 | 15.7 |
| Do | 70 | do | 500 | .4555 | do | 6 | 14.9 | 15.8 | 21.7 |
| | | | | | | Mean | 14.1 | 14.1 | 20.1 |
| Do | 70 | do | 500 | .4555 | Springfield, 2 grooved, No. 2, $\frac{1}{16}$ tin, solid-head shell. | 1 | 10.7 | 11 | 15.3 |
| Do | 70 | do | 500 | .4555 | do | 2 | 15.5 | 19.7 | 25.2 |
| Do | 70 | do | 500 | .4555 | do | 3 | 7.2 | 21.3 | 22.6 |
| Do | 70 | do | 500 | .4555 | do | 4 | 11 | 9.4 | 14.5 |
| Do | 70 | do | 500 | .4555 | do | 5 | 13.4 | 12.3 | 18.2 |
| Do | 70 | do | 500 | .4555 | do | 6 | 12.2 | 17.7 | 21.5 |
| | | | | | | Mean | 11.7 | 15.2 | 19.5 |
| Do | 70 | do | 500 | .4555 | Springfield, 2 grooved, No. 2, $\frac{1}{16}$ tin, folded-head shell. | 1 | 19.5 | 17.7 | 26.4 |
| Do | 70 | do | 500 | .4555 | do | 2 | 10.8 | 15 | 18.5 |
| Do | 70 | do | 500 | .4555 | do | 3 | 14.1 | 12.1 | 18.6 |
| Do | 70 | do | 500 | .4555 | do | 4 | 8.5 | 20.7 | 22.4 |
| Do | 70 | do | 500 | .4555 | do | 5 | 10.8 | 6.3 | 12.5 |
| Do | 70 | do | 500 | .4555 | do | 6 | 13.6 | 10.7 | 17.3 |
| | | | | | | Mean | 12.9 | 13.8 | 19.3 |
| Do | 70 | do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin, solid-head shell. | 1 | 12.6 | 12.2 | 17.5 |
| Do | 70 | do | 500 | .4555 | do | 2 | 13.2 | 5 | 14.1 |
| Do | 70 | do | 500 | .4555 | do | 3 | 10.4 | 11.7 | 15.7 |
| Do | 70 | do | 500 | .4555 | do | 4 | 13.4 | 9.6 | 16.5 |
| Do | 70 | do | 500 | .4555 | do | 5 | 9.4 | 11.6 | 14.9 |
| Do | 70 | do | 500 | .4555 | do | 6 | 7.9 | 9.6 | 12.4 |
| | | | | | | Mean | 11.1 | 9.9 | 15.2 |
| Do | 70 | do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin, folded-head shell. | 1 | 12.2 | 17.2 | 21.1 |
| Do | 70 | do | 500 | .4555 | do | 2 | 9.8 | 10.3 | 14.2 |
| Do | 70 | do | 500 | .4555 | do | 3 | 13.3 | 12.1 | 18 |
| Do | 70 | do | 500 | .4555 | do | 4 | 19.1 | 14.3 | 23.9 |
| Do | 70 | do | 500 | .4555 | do | 5 | 12.2 | 10.6 | 16.2 |
| Do | 70 | do | 500 | .4555 | do | 6 | 11.1 | 8 | 13.7 |
| [Strong wind from the right and rear.] | | | | | | Mean | 12.9 | 12.1 | 17.8 |
| Sept. 30, 1880. Service | 70 | Service | 405 | .458 | Service, $\frac{1}{16}$ tin | 1 | 21.8 | 10.1 | 24 |
| Do | 70 | Hazard, F. G. | 500 | .4555 | Springfield, 2 grooved, $\frac{1}{16}$ tin, folded-head shell. | 1 | 7.4 | 17.9 | 19.4 |
| Do | 70 | do | 500 | .4555 | Springfield, 3 grooved $\frac{1}{16}$ tin, solid-head shell. | 1 | 5.4 | 12.8 | 13.9 |
| Do | 70 | do | 500 | .4555 | do | 2 | 13.2 | 11.8 | 19.3 |
| | | | | | | Mean | 10.3 | 12.3 | 16.6 |

800 *yards range*—Continued.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 30, 1880. | *Grs.* | | *Grs.* | | | | | | |
| Service | 70 | Hazard, F. G. | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin, folded-head shell. | 1 | 8.1 | 12.5 | 14.9 |
| Do | 70 | do | 500 | .4555 | do | 2 | 14.5 | 12.7 | 19.3 |
| Light wind from right and rear. | | | | | | Mean. | 11.3 | 12.6 | 17.1 |
| Oct. 1, 1880. | | | | | | | | | |
| Service | 70 | Service | 405 | .458 | Service, $\frac{1}{16}$ tin | 1 | 10.9 | 18.5 | 21.5 |
| Do | 70 | do | 405 | .458 | do | 2 | 18.3 | 13.0 | 22.5 |
| Do | 70 | do | 405 | .458 | do | 3 | 10.8 | 11.0 | 15.4 |
| | | | | | | Mean. | 13.3 | 14.1 | 19.8 |
| Do | 70 | Hazard, F. G. | 500 | .4555 | Springfield, 2 grooved, $\frac{1}{16}$ tin, solid-head shell. | 1 | 10.6 | 8.7 | 13.7 |
| Do | 70 | do | 500 | .4555 | do | 2 | 9.9 | 18.4 | 20.9 |
| | | | | | | Mean. | 10.2 | 13.6 | 17.3 |
| Do | 70 | do | 500 | .4555 | Springfield, 2 grooved, $\frac{1}{16}$ tin, folded-head shell. | 1 | 19.8 | 25.5 | 32.3 |
| Do | 70 | do | 500 | .4555 | do | 2 | 8.9 | 12.1 | 15 |
| | | | | | | Mean. | 14.3 | 18.8 | 23.6 |
| Do | 70 | do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin, solid-head shell. | 1 | 6.4 | 9.6 | 11.5 |
| Do | 70 | do | 500 | .4555 | do | 2 | 6.9 | 13.9 | 15.5 |
| | | | | | | Mean. | 6.6 | 11.7 | 13.5 |
| Do | 70 | do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin, folded-head shell. | 1 | 9.6 | 19.1 | 21.4 |
| Do | 70 | do | 500 | .4555 | do | 2 | 9.8 | 10.4 | 14.3 |
| | | Light | wind | from | the right and rear. | Mean. | 9.7 | 14.7 | 17.8 |
| Oct. 2, 1880. | | | | | | | | | |
| Service, long-chamber. | 80 | do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin. | 1 | 5.2 | 7.1 | 8.8 |
| Do | 80 | do | 500 | .4555 | do | 2 | 11.7 | 11 | 16.1 |
| Do | 80 | do | 500 | .4555 | do | 3 | 11 | 8.2 | 13.7 |
| Do | 80 | do | 500 | .4555 | do | 4 | 18 | 15.4 | 23.7 |
| | | | | | | Mean. | 11.5 | 10.4 | 15.6 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | do | 500 | .4555 | do | 1 | 13.5 | 11.1 | 17.5 |
| Do | 80 | do | 500 | .4555 | do | 2 | 11.3 | 10.8 | 15.6 |
| Do | 80 | do | 500 | .4555 | do | 3 | 9.9 | 15.5 | 18.4 |
| Do | 80 | do | 500 | .4555 | do | 4 | 5.5 | 14.7 | 15.7 |
| | | | | | | Mean. | 10 | 13 | 16.8 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | do | 500 | .4555 | do | 1 | 22.6 | 13.8 | 26.5 |
| Do | 80 | do | 500 | .4555 | do | 2 | 12.4 | 7.7 | 14.6 |
| Do | 80 | do | 500 | .4555 | do | 3 | 18.6 | 12.3 | 22.3 |
| Do | 80 | do | 500 | .4555 | do | 4 | 12 | 11.6 | 16.7 |
| | | | | | | Mean. | 16.4 | 11.3 | 20 |

500 *yards range.*

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Deviation. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| Light breeze from right and rear. | | | | | | | | | |
| July 16, 1880. Service | 70 | Hazard, F. G. | 505 | .4555 | Springfield, 2 grooved, No. 1, $\frac{1}{16}$ tin. | 1 | 4.2 | 4.8 | 6.4 |
| Do | 70 | ....do | 505 | .4555 | ......do | 2 | 7 | 6.2 | 9.4 |
| Do | 70 | ....do | 505 | .4555 | ......do | 3 | 5.6 | 5.4 | 7.8 |
| Do | 70 | ....do | 505 | .4555 | ......do | 4 | 5.6 | 3.4 | 6.6 |
| Do | 70 | ....do | 505 | .4555 | ......do | 5 | 6.4 | 6.6 | 9.2 |
| | | | | | | Mean. | 5.8 | 5.3 | 7.9 |
| July 17, 1880. Service | 70 | ....do | 505 | .4555 | ......do | 1 | 4.8 | 5.5 | 7.3 |
| Do | 70 | ....do | 505 | .4555 | ......do | 2 | 3.1 | 6.1 | 6.9 |
| Do | 70 | ....do | 505 | .4555 | ......do | 3 | 4 | 5.8 | 7.1 |
| Do | 70 | ....do | 505 | .4555 | ......do | 4 | 8.3 | 6.8 | 10.8 |
| | | | | | | Mean. | 5 | 6 | 8 |
| Do | 70 | ....do | 405 | .458 | Service, 1 groove out, $\frac{1}{16}$ tin. | 1 | 4.7 | 5.3 | 7.1 |
| Do | 70 | ....do | 405 | .458 | ......do | 2 | 7.2 | 3.4 | 8 |
| Do | 70 | ....do | 405 | .458 | ......do | 3 | 9.3 | 8.1 | 12.3 |
| | | | | | | Mean. | 7.3 | 5.6 | 9.1 |
| July 28, 1880. Service, long-chamber. | 80 | ....do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin. | 1 | 2.4 | 5 | 5.5 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 4.8 | 4.4 | 6.5 |
| | | | | | | Mean. | 3.6 | 4.7 | 6 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | ....do | 500 | .4555 | ......do | 1 | 9.2 | 4 | 10 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | ....do | 500 | .4555 | ......do | 1 | 3.7 | 4.8 | 6.1 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 5 | 6.4 | 8.1 |
| | | | | | | Mean. | 4.3 | 5.6 | 7.1 |
| July 30, 1880. Service | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, No. 1, $\frac{1}{16}$ tin. | 1 | 2.8 | 5.3 | 5.8 |
| Do | 70 | ....do | 505 | .4555 | ......do | 2 | 4.3 | 6 | 7.4 |
| Do | 70 | ....do | 505 | .4555 | ......do | 3 | 4.8 | 3.8 | 6.1 |
| Do | 70 | ....do | 505 | .4555 | ......do | 4 | 3.8 | 4.5 | 5.9 |
| Do | 70 | ....do | 505 | .4555 | ......do | 5 | 5.6 | 4.5 | 7.2 |
| Do | 70 | ....do | 505 | .4555 | ......do | 6 | 4.2 | 4.2 | 6 |
| Do | 70 | ....do | 505 | .4555 | ......do | 7 | 3.5 | 5.2 | 6.3 |
| Do | 70 | ....do | 505 | .4555 | ......do | 8 | 4.2 | 5.2 | 6.7 |
| Do | 70 | ....do | 505 | .4555 | ......do | 9 | 7 | 6.2 | 9.3 |
| Do | 70 | ....do | 505 | .4555 | ......do | 10 | 6.4 | 4.8 | 8 |
| | | | | | | Mean. | 4.6 | 5.0 | 6.9 |
| Service, long-chamber. | 80 | ....do | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin. | 1 | 5.4 | 2.5 | 5.9 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 2.9 | 4.8 | 5.6 |
| | | | | | | Mean. | 4.1 | 3.6 | 5.7 |

500 *yards range*—Continued.

| Rifle. | Powder. |  | Bullet. |  |  | No. of targets. | Deviations. |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Weight. | Kind. | Weight. | Caliber. | Kind. |  | M. H. | M. V. | M. A. |
|  | *Grs.* |  | *Grs.* |  |  |  |  |  |  |
| July 30, 1880. 18-inch twist, 3 grooves, long-chamber. | 80 | Hazard, F. G. | 500 | .4555 | Springfield, 3 grooved, 1/16 tin. | 1 | 3.8 | 6.2 | 7.2 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 5.3 | 4 | 6.6 |
|  |  |  |  |  |  | Mean | 4.5 | 5.6 | 6.9 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | ....do | 500 | .4555 | ......do | 1 | 5 | 4.5 | 6.7 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 3.7 | 5.4 | 6.5 |
|  |  |  |  |  |  | Mean | 4.3 | 4.9 | 6.6 |
| July 31, 1880. Long-range, long-chamber. | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, No. 1, 1/16 tin. | 1 | 5.2 | 9.4 | 10.8 |
| Do | 70 | ....do | 505 | .4555 | ......do | 2 | 7.5 | 8 | 11 |
| Do | 70 | ....do | 505 | .4555 | ......do | 3 | 10 | 3.8 | 10.7 |
| Do | 70 | ....do | 505 | .4555 | ......do | 4 | 8.8 | 6.7 | 11.1 |
| Do | 70 | ....do | 505 | .4555 | ......do | 5 | 5.2 | 5.4 | 7.5 |
|  |  |  |  |  |  | Mean | 7.3 | 6.7 | 10.2 |
| Aug. 6, 1880. Service, long-chamber. | 80 | ....do | 500 | .4555 | Springfield, 3 grooved, 1/16 tin. | 1 | 5. | 5.2 | 7.2 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 4.1 | 4.9 | 6.4 |
| Do | 80 | ....do | 500 | .4555 | ......do | 3 | 4 | 4.4 | 5.9 |
|  |  |  |  |  |  | Mean | 4.4 | 4.8 | 6.5 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | ....do | 500 | .4555 | ......do | 1 | 7.2 | 3.5 | 8 |
| Do | 80 | ....do | 500 | .4355 | ......do | 2 | 4.8 | 8.2 | 9.5 |
|  |  |  |  |  |  | Mean | 6.0 | 5.8 | 8.7 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | ....do | 500 | .4555 | ......do | 1 | 7.2 | 4.9 | 8.7 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 4.8 | 4.3 | 6.4 |
| Do | 80 | ....do | 500 | .4555 | ......do | 3 | 5.7 | 4.5 | 7.3 |
|  |  |  |  |  |  | Mean | 5.9 | 4.6 | 7.5 |
| Long-range, long-chamber. | 80 | ....do | 500 | .446 | Patched, long shell, 1/16 tin. | 1 | 3.9 | 4.8 | 6.2 |
| Do | 80 | ....do | 500 | .446 | Patched, short shell, 1/16 tin. | 1 | 5.4 | 9.4 | 10.8 |
| Do | 80 | ....do | 500 | .446 | ......do | 2 | 6.6 | 4.9 | 8.2 |
| Do | 80 | ....do | 500 | .446 | ......do | 3 | 3.2 | 7.7 | 8.4 |
| Do | 80 | ....do | 500 | .446 | ......do | 4 | 5.5 | 7.2 | 9.1 |
|  |  |  |  |  |  | Mean | 5.2 | 7.3 | 9.1 |
| Aug. 7, 1880. Service | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, No. 1, 1/16 tin. | 1 | 4.8 | 4.1 | 6.4 |
| Long-range, long-chamber. | 80 | ....do | 500 | .446 | Patched, long shell, 1/16 tin. | 1 | 8.2 | 8.3 | 11.7 |
| Do | 80 | ....do | 500 | .446 | ......do | 2 | 5.3 | 6.7 | 8.6 |
|  |  |  |  |  |  | Mean | 6.7 | 7.5 | 10.1 |
| Long-range, long-chamber. | 80 | ....do | 500 | .458 | Frankford, 1/16 tin | 1 | 5.8 | 7.8 | 9.7 |
| Do | 80 | ....do | 500 | .458 | ......do | 2 | 5.6 | 6.8 | 8.8 |
|  |  |  |  |  |  | Mean | 5.7 | 7.3 | 9.2 |

500 *yards range*.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | No. of shots. | Deviations. M. H. | Deviations. M. V. | Deviations. M. V. |
|---|---|---|---|---|---|---|---|---|
| Light breeze from right and rear. | | | | | | | | |
| July 16, 1880. Service | 70 | Hazard, F. G. | 505 | .45[illegible] | 1 | 3.6 | 2.8 | 4.6 |
| Do | 70 | do | 505 | [illegible] | 2 | 3.7 | 3.7 | 5.2 |
| Do | 70 | do | 505 | [illegible] | 3 | 5.6 | 6.8 | 8.9 |
| Do | 70 | do | 505 | | 4 | 4.4 | 4.5 | 6.3 |
| | | | | | 5 | 5.7 | 4.9 | 7.6 |
| | | | | | Mean | 4.6 | 4.5 | 6.5 |
| July 17, 1880. Service | 70 | do | | | 1 | 5.5 | 6 | 8.2 |
| Do | 70 | do | | | 2 | 6.1 | 4.3 | 7.5 |
| Do | 70 | do | | | 3 | 4.7 | 7 | 8.4 |
| Do | 70 | do | | | 4 | 7.1 | 8.5 | 11.1 |
| | | | | | 5 | 7.3 | 5.9 | 9.4 |
| | | | | | 6 | 4.2 | 5.9 | 7.3 |
| | | | | | 7 | 5.2 | 5.1 | 7.3 |
| | | | | | 8 | 7 | 10.5 | 12.6 |
| Do | 70 | do | | | 9 | 6.9 | 8.8 | 11.2 |
| | | | | | 10 | 32.8 | 15.3 | 36.3 |
| Do | 70 | ... | | | Mean | 8.7 | 7.7 | 11.9 |
| Do | 70 | ... | | | | | | |
| | | | | | 1 | 6.2 | 5.1 | 8 |
| | | | | | 2 | 4 | 8.1 | 9 |
| July 28, 1880. | | | | | 3 | 4.3 | 3.5 | 5.5 |
| Service, long-chamber. | | | | | 4 | 6.4 | 7.7 | 10 |
| Do | | | | | 5 | 6.9 | 4.9 | 8.5 |
| | | | | | Mean | 5.6 | 5.9 | 8.2 |
| | | | | | 1 | 4.7 | 4.9 | 6.8 |
| 18-inch t[illegible] groov[illegible] cham[illegible] | | | | | 2 | 4.5 | 5 | 6.7 |
| | | | | | 3 | 7.4 | 8.2 | 11.1 |
| | | | | | 4 | 6.1 | 5 | 7.9 |
| 18-inch gro[illegible] ch[illegible] | | | | | 5 | 3.9 | 2.3 | 4.5 |
| | | | | | Mean | 5.5 | 5.1 | 7.4 |
| | | | | | 1 | 4.3 | 7.2 | 8.4 |
| | | | | | 2 | 6 | 10.6 | 12.2 |
| | | | | | 3 | 4.5 | 4.8 | 6.6 |
| | | | | | 4 | 3.2 | 6.8 | 7.5 |
| | | | | | 5 | 5.9 | 4.1 | 7.2 |
| | | | | | Mean | 4.8 | 6.7 | 8.4 |
| | | | | | 1 | 5.4 | 4.8 | 7.2 |
| | | | | | 2 | 8.1 | 6.3 | 10.3 |
| | | | | | 3 | 5.6 | 6.5 | 8.6 |
| | | | | | 4 | 2.2 | 7.8 | 8.1 |
| | | | | | 5 | 7.4 | 9 | 11.7 |
| | | | | | Mean | 5.7 | 6.9 | 9.2 |
| | | | | | 1 | 5.3 | 4.6 | 7 |
| | | | | | 2 | 3.1 | 5.9 | 6.7 |
| | | | | | 3 | 4.4 | 6.2 | 7.6 |
| | | | | | Mean | 4.3 | 5.6 | 7.1 |

500 *yards range*—Continued.

| | | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| | | | *Grs.* | | | | | | |
| | | ...d, F. G.. | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin. | 1 | 5.3 | 3.3 | 6.2 |
| | | ...do........ | 500 | .4555 | ......do.................. | 2 | 3.5 | 3.7 | 5.1 |
| | | ...do........ | 500 | .4555 | ......do.................. | 3 | 8.2 | 5.4 | 9.8 |
| | | | | | | Mean. | 5.7 | 5.1 | 7 |
| ... 6 ...ong- ...r | 80 | ....do........ | 500 | .4555 | ......do.................. | 1 | 4.3 | 3.5 | 5.5 |
| ........ | 80 | ....do........ | 500 | .4555 | ......do.................. | 2 | 3 | 2.7 | 4 |
| ........ | 80 | ....do........ | 500 | .4555 | ......do.................. | 3 | 4 | 3.5 | 5.3 |
| ........ | 80 | ....do........ | 500 | .4555 | ......do.................. | 4 | 5.4 | 6.5 | 8.5 |
| ........ | 80 | ....do........ | 500 | .4555 | ......do.................. | 5 | 6 | 10.2 | 11.8 |
| | | | | | | Mean. | 4.5 | 5.3 | 7 |
| Sept. 4, 1880. Service, long-chamber. | 75 | Dupont....... | 500 | .458 | Frankford, $\frac{1}{16}$ tin....... | 1 | 9.1 | 5.6 | 10.7 |
| Do......... | 75 | ....do........ | 500 | .458 | ......do.................. | 2 | 5.6 | 3.5 | 6.6 |
| Do......... | 75 | ....do........ | 500 | .458 | ......do.................. | 3 | 7.9 | 6.8 | 10.4 |
| Do......... | 75 | ....do........ | 500 | .458 | ......do.................. | 4 | 5.6 | 7.6 | 9.4 |
| | | | | | | Mean. | 7.0 | 4.9 | 9.3 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | Oriental...... | 500 | .458 | Frankford, $\frac{1}{17}$ tin....... | 1 | 8 | 9.6 | 12.5 |
| Do......... | 80 | ....do........ | 500 | .458 | ......do.................. | 2 | 11.4 | 4.6 | 12.3 |
| Do......... | 80 | ....do........ | 500 | .458 | ......do.................. | 3 | 15.5 | 9.0 | 17.9 |
| Do......... | 80 | ....do........ | 500 | .458 | ......do.................. | 4 | 9.2 | 5.8 | 10.9 |
| | | | | | | Mean. | 11 | 7.2 | 13.4 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | Hazard, F. G.. | 500 | .446 | Patched, long shell, $\frac{1}{16}$ tin. | 1 | 7.7 | 10.4 | 12.9 |
| Do......... | 80 | ....do........ | 500 | .446 | ......do.................. | 2 | 7.2 | 9.5 | 11.9 |
| Do......... | 80 | ....do........ | 500 | .446 | ......do.................. | 3 | 7 | 10.8 | 12.9 |
| | | | | | | Mean. | 7.3 | 10.2 | 12.6 |
| Sept. 6, 1880. Service, long-chamber. | 80 | Hazard, F. G.. | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin. | 1 | 7.5 | 4.5 | 8.7 |
| Do......... | 80 | ....do........ | 500 | .4555 | ......do.................. | 2 | 4.7 | 5.8 | 7.5 |
| | | | | | | Mean. | 6.1 | 5.1 | 8.1 |
| Do......... | 90 | ....do........ | 550 | .458 | Springfield, 3 grooved, $\frac{1}{16}$ tin. | 1 | 9.7 | 4.1 | 10.5 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | ....do........ | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin. | 1 | 4.4 | 4 | 5.9 |
| Do......... | 80 | ....do........ | 500 | .4555 | ......do.................. | 2 | 6.6 | 6.2 | 9.1 |
| | | | | | | Mean. | 5.5 | 5.1 | 7.5 |
| Do......... | 90 | ....do........ | 550 | .458 | Springfield, 3 grooved, $\frac{1}{16}$ tin. | 1 | 5.7 | 4.6 | 7.3 |
| 18-inch twist, 6 grooves, long-chamber. | 90 | ....do........ | 550 | .458 | ......do.................. | 1 | 6.8 | 7.8 | 10.3 |
| Do......... | 90 | ....do........ | 550 | .458 | ......do.................. | 2 | 5.3 | 5.2 | 7.4 |
| | | | | | | Mean. | 6.0 | 4.9 | 8.9 |

500 *yards range*—Continued.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. V. |
|---|---|---|---|---|---|---|---|---|---|
| | *Grs.* | | *Grs.* | | | | | | |
| Aug. 9, 1880. Service | 70 | Hazard, F. G. | 505 | .4555 | Springfield, 2 grooved, No. 1, $\frac{1}{16}$ tin. | 1 | 3.6 | 2.8 | 4.6 |
| Do | 70 | ...do | 505 | .4555 | ...do | 2 | 3.7 | 3.7 | 5.2 |
| Do | 70 | ...do | 505 | .4555 | ...do | 3 | 5.6 | 6.8 | 8.9 |
| Do | 70 | ...do | 505 | .4555 | ...do | 4 | 4.4 | 4.5 | 6.3 |
| Do | 70 | ...do | 505 | .4555 | ...do | 5 | 5.7 | 4.9 | 7.6 |
| | | | | | | Mean | 4.6 | 4.5 | 6.5 |
| Aug. 11, 1880. Service | 70 | ...do | 505 | .4555 | ...do | 1 | 5.5 | 6 | 8.2 |
| Do | 70 | ...do | 505 | .4555 | ...do | 2 | 6.1 | 4.3 | 7.5 |
| Do | 70 | ...do | 505 | .4555 | ...do | 3 | 4.7 | 7 | 8.4 |
| Do | 70 | ...do | 505 | .4555 | ...do | 4 | 7.1 | 8.5 | 11.1 |
| Do | 70 | ...do | 505 | .4555 | ...do | 5 | 7.3 | 5.9 | 9.4 |
| Do | 70 | ...do | 505 | .4555 | ...do | 6 | 4.2 | 5.9 | 7.3 |
| Do | 70 | ...do | 505 | .4555 | ...do | 7 | 5.2 | 5.1 | 7.3 |
| Do | 70 | ...do | 505 | .4555 | ...do | 8 | 7 | 10.5 | 12.6 |
| Do | 70 | ...do | 505 | .4555 | ...do | 9 | 6.9 | 8.8 | 11.2 |
| Do | 70 | ...do | 505 | .4555 | ...do | 10 | 32.8 | 15.3 | 36.3 |
| | | | | | | Mean | 8.7 | 7.7 | 11.9 |
| Aug. 16, 1880. Service | 70 | ...do | 505 | .4555 | ...do | 1 | 6.2 | 5.1 | 8 |
| Do | 70 | ...do | 505 | .4555 | ...do | 2 | 4 | 8.1 | 9 |
| Do | 70 | ...do | 505 | .4555 | ...do | 3 | 4.3 | 3.5 | 5.5 |
| Do | 70 | ...do | 505 | .4555 | ...do | 4 | 6.4 | 7.7 | 10 |
| Do | 70 | ...do | 505 | .4555 | ...do | 5 | 6.9 | 4.9 | 8.5 |
| | | | | | | Mean | 5.6 | 5.9 | 8.2 |
| Service | 70 | ...do | 505 | .4555 | Springfield, 2 grooved, No. 2, $\frac{1}{16}$ tin. | 1 | 4.7 | 4.9 | 6.8 |
| Do | 70 | ...do | 505 | .4555 | ...do | 2 | 4.5 | 5 | 6.7 |
| Do | 70 | ...do | 505 | .4555 | ...do | 3 | 7.4 | 8.2 | 11.1 |
| Do | 70 | ...do | 505 | .4555 | ...do | 4 | 6.1 | 5 | 7.9 |
| Do | 70 | ...do | 505 | .4555 | ...do | 5 | 3.9 | 2.3 | 4.5 |
| | | | | | | Mean | 5.5 | 5.1 | 7.4 |
| Aug. 18, 1880. Service | 70 | ...do | 505 | .4555 | ...do | 1 | 4.3 | 7.2 | 8.4 |
| Do | 70 | ...do | 505 | .4555 | ...do | 2 | 6 | 10.6 | 12.2 |
| Do | 70 | ...do | 505 | .4555 | ...do | 3 | 4.5 | 4.8 | 6.6 |
| Do | 70 | ...do | 505 | .4555 | ...do | 4 | 3.2 | 6.8 | 7.5 |
| Do | 70 | ...do | 505 | .4555 | ...do | 5 | 5.9 | 4.1 | 7.2 |
| | | | | | | Mean | 4.8 | 6.7 | 8.4 |
| Aug. 20, 1880. Service | 70 | ...do | 490 | .4555 | Springfield, 2 grooved, No. 2, with 4 small grooves outside of shell. | 1 | 5.4 | 4.8 | 7.2 |
| Do | 70 | ...do | 490 | .4555 | ...do | 2 | 8.1 | 6.3 | 10.3 |
| Do | 70 | ...do | 490 | .4555 | ...do | 3 | 5.6 | 6.5 | 8.6 |
| Do | 70 | ...do | 490 | .4555 | ...do | 4 | 2.2 | 7.8 | 8.1 |
| Do | 70 | ...do | 490 | .4555 | ...do | 5 | 7.4 | 9 | 11.7 |
| | | | | | | Mean | 5.7 | 6.9 | 9.2 |
| Aug. 24, 1880. Service, long-chamber | 80 | Hazard, F. G. | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin. | 1 | 5.3 | 4.6 | 7 |
| Do | 80 | ...do | 500 | .4555 | ...do | 2 | 3.1 | 5.9 | 6.7 |
| Do | 80 | ...do | 500 | .4555 | ...do | 3 | 4.4 | 6.2 | 7.6 |
| | | | | | | Mean | 4.3 | 5.6 | 7.1 |

500 *yards range*—Continued.

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| Aug. 24, 1880. 18-inch twist, 3 grooves, long-chamber. | *Grs.* 80 | Hazard, F. G.. | *Grs.* 500 | .4555 | Springfield, 3 grooved, 1/16 tin. | 1 | 5.3 | 3.3 | 6.2 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 2 | 3.5 | 3.7 | 5.1 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 3 | 8.2 | 5.4 | 9.8 |
| | | | | | | Mean. | 5.7 | 5.1 | 7 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | ....do ......... | 500 | .4555 | ......do................. | 1 | 4.3 | 3.5 | 5.5 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 2 | 3 | 2.7 | 4 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 3 | 4 | 3.5 | 5.3 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 4 | 5.4 | 6.5 | 8.5 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 5 | 6 | 10.2 | 11.8 |
| | | | | | | Mean. | 4.5 | 5.3 | 7 |
| Sept. 4, 1880. Service, long-chamber. | 75 | Dupont ....... | 500 | .458 | Frankford, 1/18 tin....... | 1 | 9.1 | 5.6 | 10.7 |
| Do......... | 75 | ....do ......... | 500 | .458 | ......do................. | 2 | 5.6 | 3.5 | 6.6 |
| Do......... | 75 | ....do ......... | 500 | .458 | ......do................. | 3 | 7.9 | 6.8 | 10.4 |
| Do......... | 75 | ....do ......... | 500 | .458 | ......do................. | 4 | 5.6 | 7.6 | 9.4 |
| | | | | | | Mean. | 7.0 | 4.9 | 9.3 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | Oriental ...... | 500 | .458 | Frankford, 1/17 tin....... | 1 | 8 | 9.6 | 12.5 |
| Do......... | 80 | ....do ......... | 500 | .458 | ......do................. | 2 | 11.4 | 4.6 | 12.3 |
| Do......... | 80 | ....do ......... | 500 | .458 | ......do................. | 3 | 15.5 | 9.0 | 17.9 |
| Do......... | 80 | ....do ......... | 500 | .458 | ......do................. | 4 | 9.2 | 5.8 | 10.9 |
| | | | | | | Mean. | 11 | 7.2 | 13.4 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | Hazard, F. G.. | 500 | .446 | Patched, long shell, 1/16 tin. | 1 | 7.7 | 10.4 | 12.9 |
| Do......... | 80 | ....do ......... | 500 | .446 | ......do................. | 2 | 7.2 | 9.5 | 11.9 |
| Do......... | 80 | ....do ......... | 500 | .446 | ......do................. | 3 | 7 | 10.8 | 12.9 |
| | | | | | | Mean. | 7.3 | 10.2 | 12.6 |
| Sept. 6, 1880. Service, long-chamber. | 80 | Hazard, F. G.. | 500 | .4555 | Springfield, 3 grooved, 1/16 tin. | 1 | 7.5 | 4.5 | 8.7 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 2 | 4.7 | 5.8 | 7.5 |
| | | | | | | Mean. | 6.1 | 5.1 | 8.1 |
| Do......... | 90 | ....do ......... | 550 | .458 | Springfield, 3 grooved, 1/16 tin. | 1 | 9.7 | 4.1 | 10.5 |
| 12-inch twist, 3 grooves, long-chamber. | 80 | ....do ......... | 500 | .4555 | Springfield, 3 grooved, 1/16 tin. | 1 | 4.4 | 4 | 5.9 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 2 | 6.6 | 6.2 | 9.1 |
| | | | | | | Mean. | 5.5 | 5.1 | 7.5 |
| Do......... | 90 | ....do ......... | 550 | .458 | Springfield, 3 grooved, 1/16 tin. | 1 | 5.7 | 4.6 | 7.3 |
| 18-inch twist, 6 grooves, long-chamber. | 90 | ....do ......... | 550 | .458 | ......do................. | 1 | 6.8 | 7.8 | 10.3 |
| Do......... | 90 | ....do ......... | 550 | .458 | ......do................. | 2 | 5.3 | 5.2 | 7.4 |
| | | | | | | Mean. | 6.0 | 4.9 | 8.9 |

500 *yards range*—Continued.

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| Sept. 22, 1880. Service | *Grs.* 70 | Hazard, F. G. | *Grs.* 505 | .4555 | Springfield, 2 grooved, No. 2, folded-head shell, $\frac{1}{16}$ tin. | 1 | 8 | 11.3 | 13.8 |
| Do | 70 | ....do | 505 | .4555 | ......do | 2 | 3.2 | 7 | 7.7 |
| Do | 70 | ....do | 505 | .4555 | ......do | 3 | 5.8 | 13.5 | 14.7 |
| | | | | | | Mean. | 5.7 | 10.6 | 12.1 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3 grooved, solid-head shell, $\frac{1}{16}$ tin. | 1 | 5.6 | 4.1 | 6.9 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 5.1 | 4.3 | 6.7 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 5.1 | 5.8 | 7.4 |
| | | | | | | Mean. | 5.3 | 4.6 | 7 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3 grooved, folded-head shell, $\frac{1}{16}$ tin. | 1 | 8.1 | 6.4 | 10.3 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 6.9 | 8.2 | 10.7 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 4.7 | 4.5 | 6.5 |
| | | | | | | Mean. | 6.6 | 6.4 | 9.2 |
| Do | 70 | ....do | 405 | .458 | Service, 3 grooved, folded-head shell, $\frac{1}{16}$ tin. | 1 | 7.8 | 8.5 | 11.5 |
| Do | 70 | ....do | 405 | .458 | ......do | 2 | 8.9 | 7.6 | 11.7 |
| Do | 70 | ....do | 405 | .458 | ......do | 3 | 6.5 | 5.2 | 8.3 |
| | | | | | Strong wind from left and rear. | Mean. | 7.7 | 7.1 | 10.5 |
| Sept. 23, 1880. Service | 70 | ....do | 405 | .458 | Service, $\frac{1}{16}$ tin | 1 | 5.3 | 10 | 11.3 |
| Do | 70 | ....do | 405 | .458 | ......do | 2 | 7 | 4.4 | 8.3 |
| Do | 70 | ....do | 405 | .458 | ......do | 3 | 4.9 | 9.8 | 11 |
| Do | 70 | ....do | 405 | .458 | ......do | 4 | 4.9 | 10.8 | 11.9 |
| Do | 70 | ....do | 405 | .458 | ......do | 5 | 7 | 7.7 | 10.4 |
| Do | 70 | ....do | 405 | .458 | ......do | 6 | 4.6 | 9.4 | 10.5 |
| | | | | | | Mean. | 5.6 | 8.7 | 10.6 |
| Do | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, No. 2, folded-head shell, $\frac{1}{16}$ tin. | 1 | 8 | 10.8 | 13.4 |
| Do | 70 | ....do | 505 | .4555 | ......do | 2 | 5.6 | 7.9 | 9.7 |
| Do | 70 | ....do | 505 | .4555 | ......do | 3 | 4.3 | 9.1 | 10.1 |
| Do | 70 | ....do | 505 | .4555 | ......do | 4 | 11.1 | 13.1 | 14 |
| Do | 70 | ....do | 505 | .4555 | ......do | 5 | 3.8 | 8.5 | 9.3 |
| Do | 70 | ....do | 505 | .4555 | ......do | 6 | 5.4 | 9.4 | 10.8 |
| | | | | | | Mean. | 6.4 | 9.8 | 11.2 |
| Do | 70 | Hazard, F. G. | 500 | .4555 | Springfield, 3 grooved, solid-head shell, $\frac{1}{16}$ tin. | 1 | 4.2 | 6.3 | 7.6 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 4.8 | 5.2 | 7.1 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 5.2 | 5. | 7.2 |
| Do | 70 | ....do | 500 | .4555 | ......do | 4 | 7.0 | 6.6 | 9.6 |
| Do | 70 | ....do | 500 | .4555 | ......do | 5 | 3.8 | 5.1 | 6.4 |
| Do | 70 | ....do | 500 | .4555 | ......do | 6 | 5.8 | 6.2 | 8.5 |
| | | | | | | Mean. | 5.1 | 5.7 | 7.6 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3 grooved, folded-head shell, $\frac{1}{16}$ tin. | 1 | 4.9 | 5.7 | 7.3 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 4.4 | 5.9 | 7.4 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 4.5 | 5 | 6.7 |

500 *yards range*—Continued.

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| Sept. 23, 1880. | *Grs.* | | *Grs.* | | | | | | |
| Service | 70 | Hazard, F. G. | 500 | .4555 | Springfield, 3 grooved, folded-head shell, 1/16 tin. | 4 | 5.6 | 6 | 8.2 |
| Do | 70 | ....do | 500 | .4555 | ......do | 5 | 3.4 | 2.9 | 4.5 |
| Do | 70 | ....do | 500 | .4555 | ......do | 6 | 6.6 | 5.1 | 8.3 |
| | | | | | | Mean. | 4.9 | 5.1 | 7.1 |
| Sept. 24, 1880. | | | | | | | | | |
| Service | 70 | Service | 405 | .458 | Service 1/16 tin | 1 | 3.6 | 6.5 | 7.4 |
| Do | 70 | F. G. Hazard | 505 | .4555 | Springfield, 2 grooved, folded-head shell, 1/16 tin. | 1 | 7.7 | 5.9 | 9.7 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3 grooved, folded-head shell, 1/16 tin. | 1 | 3.8 | 6.6 | 7.6 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3 grooved, solid-head shell, 1/16 tin. | 1 | 5.7 | 5 | 7.6 |
| 18-inch twist, 3 grooves, long chamber. | 80 | ....do | 500 | .4555 | Springfield, 3 grooved, 1/16 tin. | 1 | 5.4 | 9.9 | 11.3 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 6.6 | 5.4 | 8.5 |
| | | | | | | Mean.. | 6 | 7.6 | 9.9 |
| Oct. 6, 1880. | | | | | | | | | |
| Service | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, No. 2, solid-head shell, 1/16 tin; lubricated with Japan wax. | 1 | 5.9 | 4.6 | 7.5 |
| Do | 70 | ....do | 505 | .4555 | ......do | 2 | 6.7 | 5.4 | 8.6 |
| Do | 70 | ....do | 505 | .4555 | ......do | 3 | 4.1 | 7.7 | 8.7 |
| Do | 70 | ....do | 505 | .4555 | ......do | 4 | 6.1 | 7.8 | 9.9 |
| Do | 70 | ....do | 505 | .4555 | ......do | 5 | 6.3 | 9.6 | 11.5 |
| | | | | | | Mean. | 5.8 | 7.0 | 9.2 |
| Service | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, No. 2, folded-head shell, 1/16 tin; lubricated with Japan wax. | 1 | 8.6 | 10.5 | 13.6 |
| Do | 70 | ....do | 505 | .4555 | ......do | 2 | 6.4 | 12.4 | 14 |
| Do | 70 | ....do | 505 | .4555 | ......do | 3 | 8.9 | 5 | 10.2 |
| Do | 70 | ....do | 505 | .4555 | ......do | 4 | 7.1 | 8.6 | 11.1 |
| Do | 70 | ....do | 505 | .4555 | ......do | 5 | 6.7 | 7.7 | 10.2 |
| | | | | | | Mean. | 7.5 | 8.8 | 11.8 |
| Aug. 25, 26, 1880. | | | | | | | | | |
| Service long-chamber. | 80 | ....do | 500 | .4555 | Springfield, 3 grooved, 1/16 tin. | 1 | 3.8 | 1.7 | 4.2 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 2.6 | 1.9 | 3.2 |
| Do | 80 | ....do | 500 | .4555 | ......do | 3 | 2.7 | 2.9 | 4 |
| Do | 80 | ....do | 500 | .4555 | ......do | 4 | 4.3 | 4 | 5.9 |
| | | | | | | Mean. | 3.3 | 2.6 | 4.3 |
| 16-inch twist, 3 grooves, long-chamber. | 80 | ....do | 500 | .4555 | ......do | 1 | 2.8 | 2.1 | 3.5 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 4 | 3.4 | 5.2 |
| Do | 80 | ....do | 500 | .4555 | ......do | 3 | 3.8 | 2.5 | 4.5 |
| Do | 80 | ....do | 500 | .4555 | ......do | 4 | 2.9 | 2.5 | 3.8 |
| | | | | | | Mean. | 3.4 | 2.6 | 4.25 |
| 13-inch twist, 6 grooves, long-chamber. | 80 | ....do | 500 | .4555 | ......do | 1 | 3 | 1.8 | 3.5 |
| Do | 80 | ....do | 500 | .4555 | ......do | 2 | 3.2 | 2.4 | |

500 *yards range*—Continued.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 25, 26, 1880. | *Grs* | | *Grs.* | | | | | | |
| 18-inch twist, 6 grooves, long-chamber. | 80 | F. G. Hazard.. | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{18}$ tin. | 3 | 3.8 | 3.3 | 5 |
| Do......... | 80 | ....do ......... | 500 | .4555 | ......do................. | 4 | 3.1 | 2.8 | 4.1 |
| | | | | | | Mean. | 3.3 | 2.6 | 4.15 |
| Sept. 1, 1880. | | | | | | | | | |
| Service, long-chamber. | 80 | Oriental ...... | 500 | .458 | Frankford, $\frac{1}{17}$ tin. ..... | 1 | 7.5 | 5.7 | 9.4 |
| Do......... | 80 | Hazard, F. G.. | 500 | .458 | ......do................. | 1 | 3.4 | 5.2 | 6.2 |
| Do......... | 80 | Dupont........ | 500 | .458 | Frankford, $\frac{1}{12}$ tin....... | 1 | 5.1 | 2.7 | 5.8 |
| Do......... | 75 | ....do ......... | 500 | .458 | ......do................. | 1 | 2.8 | 1.9 | 3.4 |
| Do......... | 80 | Hazard, F. G.. | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{18}$ tin. | 1 | 3.3 | 3.8 | 5 |
| Do......... | 80 | ....do ......... | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{18}$ tin. | 1 | 1.6 | 2.1 | 2.7 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | Oriental ...... | 500 | .458 | Frankford, $\frac{1}{17}$ tin....... | 1 | 4.5 | 3.5 | 5.7 |
| Do......... | 80 | Hazard, F. G.. | 500 | .458 | ......do................. | 1 | 3.5 | 5 | 6.1 |
| Do......... | 80 | Dupont........ | 500 | .458 | Frankford, $\frac{1}{12}$ tin....... | 1 | 4.5 | 3.9 | 6 |
| Do......... | 75 | ....do ......... | 500 | .458 | ......do................. | 1 | 2.7 | 4 | 4.8 |
| Do......... | 80 | Hazard, F. G.. | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{18}$ tin. | 1 | 3.9 | 2.4 | 4.7 |
| Do......... | 80 | ....do ......... | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{18}$ tin. | 1 | 2.5 | 3.8 | 4.5 |
| 18-inch twist, 6 grooves, long-chamber. | 80 | Oriental ...... | 500 | .458 | Frankford, $\frac{1}{17}$ tin....... | 1 | 8.4 | 7.5 | 11.3 |
| Do......... | 80 | Hazard, F. G.. | 500 | .458 | ......do................. | 1 | 2.4 | 2.8 | 3.7 |
| Do......... | 80 | Dupont........ | 500 | .458 | Frankford, $\frac{1}{12}$ tin....... | 1 | 3.7 | 4.6 | 5.9 |
| Do......... | 75 | ....do ......... | 500 | .458 | ......do................. | 1 | 4.3 | 3.1 | 5.3 |
| Do......... | 80 | Hazard, F. G.. | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{18}$ tin. | 1 | 5.3 | 2.8 | 6 |
| Do......... | 80 | ....do ......... | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{18}$ tin. Calm. | 1 | 3.4 | 3.9 | 5.2 |
| Sept. 9, 1880. | | | | | | | | | |
| Service, long-chamber. | 80 | ....do ......... | 500 | .458 | Frankford, $\frac{1}{12}$ tin....... | 1 | 4.3 | 5.8 | 7.2 |
| Do......... | 80 | Dupont........ | 500 | .458 | ......do................. | 1 | 5 | 5.8 | 7.7 |
| 18-inch twist, 3 grooves, long-chamber. | 80 | Hazard, F. G.. | 500 | .458 | ......do................. | 1 | 4 | 3.4 | 5.2 |
| Do......... | 80 | Dupont........ | 500 | .458 | ......do................. | 1 | 4.2 | 5.6 | 7 |
| | | Heavy | wind | from | left and front. | | | | |

300 *yards range.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| 18-inch twist, 6 grooves, long-chamber. | 80 | Hazard, F. G.. | 500 | .458 | Frankford, $\frac{1}{17}$ tin....... | 1 | 2.3 | 3.8 | 4.4 |
| Do......... | 80 | Oriental ...... | 500 | .458 | Frankford, $\frac{1}{12}$ tin....... Heavy wind from left and front. | 1 | 4.1 | 3.9 | 5.7 |
| Sept. 22, 1880. | | | | | | | | | |
| Service ........ | 70 | Hazard, F. G.. | 500 | .4555 | Springfield, 2 grooved, No. 2, solid-head shell, $\frac{1}{18}$ tin. | 1 | 2.4 | 2.4 | 3.4 |
| Do......... | 70 | ....do ......... | 500 | .4555 | ......do................. | 2 | 2.6 | 3.2 | 4.1 |
| Do......... | 70 | ....do ......... | 500 | .4555 | ......do................. | 3 | 2.5 | 2.3 | 3.4 |
| Do......... | 70 | ....do ......... | 500 | .4555 | ......do................. | 4 | 2.6 | 3.3 | 4.2 |
| | | | | | | Mean. | 2.4 | 2.5 | 3.6 |

300 *yards range*—Continued.

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| Sept. 22, 1880. | *Grs.* | | *Grs.* | | | | | | |
| Service | 70 | Hazard, F. G. | 500 | .4555 | Springfield, 2 grooved, No. 2, folded-head shell, 1/8 tin. | 1 | 4.2 | 4.6 | 6.2 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 3.1 | 3.7 | 4.8 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 3.4 | 3.4 | 4.8 |
| Do | 70 | ....do | 500 | .4555 | ......do | 4 | 3.2 | 2.6 | 4.1 |
| | | | | | | Mean. | 3.6 | 3.4 | 5.0 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3 grooved, solid-head shell, 1/8 tin. | 1 | 3.6 | 3.4 | 4.9 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 1.8 | 1.4 | 2.3 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 2.6 | 2.3 | 3.5 |
| Do | 70 | ....do | 500 | .4555 | ......do | 4 | 3.5 | 2.4 | 4.2 |
| | | | | | | Mean. | 2.7 | 2.3 | 3.7 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3 grooved, folded-head shell, 1/8 tin. | 1 | 2.2 | 4.4 | 4.9 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 1.9 | 2.4 | 3.1 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 4.6 | 5.1 | 6.9 |
| Do | 70 | ....do | 500 | .4555 | ......do | 4 | 2.9 | 3 | 4.2 |
| | | | | | | Mean. | 2.8 | 3.6 | 4.8 |
| Do | 70 | ....do | 405 | .458 | Service, 1/8 tin | 1 | 4.3 | 5.2 | 6.7 |
| Do | 70 | ....do | 405 | .458 | ......do | 2 | 4.8 | 2 | 5.2 |
| Do | 70 | ....do | 405 | .458 | ......do | 3 | 3.3 | 2.7 | 4.3 |
| Do | 70 | ....do | 405 | .458 | ......do | 4 | 5.7 | 4.3 | 7.1 |
| | | | | | Strong wind from left and rear. | Mean. | 4.5 | 3.5 | 5.8 |
| Sept. 24, 1880. | | | | | | | | | |
| Service | 70 | ....do | 405 | .458 | Service, 1/8 tin | 1 | 2.7 | 4.1 | 4.9 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 2 grooved, No. 2, solid-head shell, 1/8 tin. | 1 | 2.7 | 2.8 | 3.9 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 2 grooved, No. 2, folded-head shell, 1/8 tin. | 1 | 2.8 | 2.5 | 3.8 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3 grooved, solid-head shell, 1/8 tin. | 1 | 3.4 | 4.4 | 5.5 |
| Do | 70 | ....do | 500 | .4555 | Springfield, 3 grooved, folded-head shell, 1/8 tin. | 1 | 2.5 | 2.2 | 3.3 |

NATIONAL ARMORY, SPRINGFIELD, MASS.,
*October* 25, 1880.

SIR: Since my report of October 13, 1880, cartridges have been prepared for the service rifle with the solid-head shell of Frankford make, the 500 grains 3-grooved bullet and 70 grains Dupont powder. This powder was received from Frankford arsenal last summer, and is understood to have met with much favor at that post. It was therefore desirable to ascertain whether or not it would prove satisfactory when used in the solid-head shell with the heavy bullet.

For this purpose a service rifle was taken and 10 targets of ten shots each made at 500 yards, and 12 targets at 1,000 yards. The results were exceedingly satisfactory.

Five new service rifles were then taken indiscriminately from the rack

and two targets made with each at the same ranges as before. The weather was, it is true, very favorable for these trials, but the accuracy was so good as almost to justify the adoption of this combination without further trial.

Additional targets, however, were made at 300 and 800 yards with marked success.

It was observed that the elevation of the sight at 500 yards range was but little more than that required for the service cartridge, or about 525 yards.

At 1,000 yards it varied slightly with different rifles from 975 to 1,000 yards, showing that no change need be made in the sight as now issued, the marksmen readily determining the slight correction necessary for any range should any of these cartridges be issued for trial.

The accompanying abstract shows accuracy at the various ranges tried, velocity, recoil, and pressure per square inch of bore.

An abstract of results obtained with cartridges prepared at this post with 70 and 80 grain charges, and sent at my request to Frankford arsenal for trial in comparison with the service, is also given.

As a result of continuous trials for about one year with eight different rifles, viz, a service, 18-inch twist with 3 service grooves, 18-inch twist with 6 grooves, 19⅝-inch twist with 6 grooves, these with chambers of service length, and similar rifles with chambers for a 2.4 inch shell, many varieties of cartridges being used, it may be safely asserted that with a reasonably good system of rifling increase in accuracy is to be sought for chiefly by improvement in the cartridge and not in the gun; and that of this more depends on the bullet than any other element of the cartridge, assuming as before a reasonably good cartridge as the basis on which improvement is to be made. In this case we have as a foundation the service rifle and service (Frankford arsenal) cartridge, which, taken together, have through a test of many years proved worthy of the highest praise. It is highly significant, therefore, that after such extended trials as have been made during the last year we find ourselves unable to show that any change is necessary beyond that of the bullet and the solid-head reloading shell, which the great interest now taken in target practice has rendered a necessity on the score of economy only.

Very respectfully, your obedient servant,

JOHN E. GREER,
*Captain of Ordnance, U. S. A.*

To the COMMANDING OFFICER, *National Armory.*

*Abstract of results of firing with Springfield bullet, Dupont powder, and solid-head shell, at ranges of 1,000, 800, 500, and 300 yards.*

| Rifle. | Powder. | | Bullet. | | | 1,000 yds. | | 800 yds. | | 500 yds. | | 300 yds. | | No. of shot. | *Velocities. | | Foot-pounds. | Pressures. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | No. of targets. | Mean deviations. | No. of targets. | Mean deviations. | No. of targets. | Mean deviations. | No. of targets. | Mean deviations. | | Le Boulengé chronograph. | Benton's electro-ballistic. | | Pounds per square inch. | |
| | *Grs.* | | *Grs.* | | | | | | | | | | | | | | | | |
| Service .. | 70 | Dupont . | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin | 22 | 21.4 | 11 | 13.9 | 20 | 7.8 | 10 | 4.2 | 1 | 1295.5 | 1280.1 | 14.4 | 33,233 | Elevation of sight at 1,000 yards range from 975 to same as graduated; at 800 yards, 775; at 500 yards, 525; at 300 yards, 310. |
| Do.... | 70 | ...do .... | 500 | .4555 | ......do | 22 | 21.4 | 11 | 13.9 | 20 | 7.8 | 10 | 4.2 | 2 | 1284.5 | 1281.3 | 14.4 | 33,233 | |
| Do.... | 70 | ...do .... | 500 | .4555 | ......do | 22 | 21.4 | 11 | 13.9 | 20 | 7.8 | 10 | 4.2 | 3 | 1288.0 | 1286.5 | 14.4 | 33,233 | |
| Do.... | 70 | ...do .... | 500 | .4555 | ......do | 22 | 21.4 | 11 | 13.9 | 20 | 7.8 | 10 | 4.2 | 4 | 1288.0 | 1289.1 | 14.4 | 33,233 | |
| Do.... | 70 | ...do .... | 500 | .4555 | ......do | 22 | 21.4 | 11 | 13.9 | 20 | 7.8 | 10 | 4.2 | 5 | 1297.0 | 1293.7 | 14.4 | 33,233 | |
| Do.... | 70 | ...do .... | 500 | .4556 | ......do | 22 | 21.4 | 11 | 13.9 | 20 | 7.8 | 10 | 4.2 | 6 | 1289.0 | 1292.7 | 14.4 | 33,233 | |
| | | | | | | | | | | | | | | Mean .......... | 1290.3 | 1288.7 | | | |
| | | | | | | | | | | | | | | Extreme variation ........ | 12.5 | 12.4 | | | |
| | | | | | | | | | | | | | | Mean variation | 3.9 | 3.2 | | | |
| | | | | | | | | | | | | | | Mean by both machines .... | 1289.5 | | | | |

* Taken simultaneously by the two machines with independent circuits.

*Abstract of results of firing at Frankford Arsenal with Springfield bullet, 70 and 80 grains powder, at range of 500 yards.*

| Rifle. | Powder. | | Bullet. | | | No. of target. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | | |
| | *Grains.* | | *Grains.* | | | | | |
| Service .............................. | 70 | Service ....... | 405 | .458 | Service .............................. | 6 | 9.8 | *Folded-head shell. |
| Do.............................. | 70 | Hazard, F. G.. | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin ............ | 6 | 8.9 | Do. |
| Do.............................. | 70 | ....do ........ | 500 | .4555 | ......do .............................. | 6 | 8.1 | Solid-head shell. |
| Service, long-chamber .................... | 80 | ....do ........ | 500 | .4555 | ......do .............................. | 6 | 7.6 | Do. |

1,000 *yards range.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| Oct. 16, 1880. | *Grs.* | | *Grs.* | | | | | | |
| Service | 70 | Dupont | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin, solid-head shell. | 1 | 10.3 | 17.8 | 20.6 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 5.7 | 11.4 | 12.7 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 9.3 | 15.6 | 18.1 |
| Do | 70 | ....do | 500 | .4555 | ......do | 4 | 16.5 | 9.8 | 19.2 |
| Do | 70 | ....do | 500 | .4555 | ......do | 5 | 6.4 | 9.5 | 11.5 |
| Do | 70 | ....do | 500 | .4555 | ......do | 6 | 20.6 | 22.6 | 30.6 |
| Do | 70 | ....do | 500 | .4555 | ......do | 7 | 16.1 | 16.4 | 23 |
| Do | 70 | ....do | 500 | .4555 | ......do | 8 | 14.1 | 14.2 | 20 |
| Do | 70 | ....do | 500 | .4555 | ......do | 9 | 7.3 | 13.2 | 15.1 |
| Do | 70 | ....do | 500 | .4555 | ......do | 10 | 10.2 | 23.2 | 25.3 |
| Do | 70 | ....do | 500 | .4555 | ......do | 11 | 10.9 | 17.9 | 21 |
| Do | 70 | ....do | 500 | .4555 | ......do | 12 | 16.2 | 18.9 | 24.9 |
| | | | | | Calm. | Mean | 11.9 | 15.9 | 20.2 |
| Oct. 19, 1880. | | | | | | | | | |
| Calm. Service | 70 | Dupont | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin, solid-head shell. | 1 | 10.3 | 14.5 | 17.6 |
| Calm. Do | 70 | ....do | 500 | .4555 | ......do | 2 | 12.4 | 13 | 18 |
| Calm. Do | 70 | ....do | 500 | .4555 | ......do | 3 | 11.2 | 17.2 | 20.5 |
| Service | 70 | ....do | 500 | .4555 | ......do | 4 | 13.8 | 16.1 | 21.2 |
| Do | 70 | ....do | 500 | .4555 | ......do | 5 | 17.2 | 15.8 | 23.4 |
| Do | 70 | ....do | 500 | .4555 | ......do | 6 | 15.7 | 19 | 24.6 |
| Do | 70 | ....do | 500 | .4555 | ......do | 7 | 6.7 | 21.2 | 22.2 |
| Do | 70 | ....do | 500 | .4555 | ......do | 8 | 22.2 | 18.1 | 28.6 |
| Do | 70 | ....do | 500 | .4555 | ......do | 9 | 22.7 | 16.5 | 28.1 |
| Do | 70 | ....do | 500 | .4555 | ......do | 10 | 16.2 | 17.7 | 24 |
| Light breeze from the right and front. | | | | | | Mean | 14.8 | 16.9 | 22.8 |

800 *yards range.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| Oct. 26, 1880. | *Grs.* | | *Grs.* | | | | | | |
| Service | 70 | Dupont | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin, solid-head shell. | 1 | 9.2 | 8.2 | 12.3 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 9.9 | 5 | 11.1 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 7.4 | 8.3 | 11.1 |
| Do | 70 | ....do | 500 | .4555 | ......do | 4 | 12.3 | 8.5 | 15 |
| Do | 70 | ....do | 500 | .4555 | ......do | 5 | 7.8 | 11.7 | 14.1 |
| | | | | | Calm. | Mean | 9.3 | 8.3 | 12.7 |
| Service | 70 | Dupont | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin, solid-head shell. | 1 | 10.6 | 10 | 14.6 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 15.4 | 8.3 | 17.5 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 8.4 | 11.4 | 14.2 |
| Do | 70 | ....do | 500 | .4555 | ......do | 4 | 10.4 | 13.8 | 17.3 |
| Do | 70 | ....do | 500 | .4555 | ......do | 5 | 7 | 11.6 | 13.5 |
| Do | 70 | ....do | 500 | .4555 | ......do | 6 | 9.8 | 7.4 | 12.3 |
| | | Light breeze from left and front; dark and cloudy. | | | | Mean | ...... | ...... | 14.9 |

500 *yards range.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|
| Oct. 14, 1880. | *Grs.* | | *Grs.* | | | | | | |
| Service | 70 | Dupont | 500 | .4555 | Springfield, 3 grooved, $\frac{1}{16}$ tin, solid-head shell. | 1 | 4.3 | 8.2 | 9.4 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 6.1 | 4.5 | 7.6 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 5.2 | 5.9 | 7.9 |
| Do | 70 | ....do | 500 | .4555 | ......do | 4 | 6.5 | 7.2 | 9.7 |
| Do | 70 | ....do | 500 | .4555 | ......do | 5 | 5.1 | 3.3 | 6.1 |

500 *yards range*—Continued.

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M.H. | Deviations. M.V. | Deviations. M.A. |
|---|---|---|---|---|---|---|---|---|---|
| Oct. 14, 1880. | *Grs.* | | *Grs.* | | | | | | |
| Service | 70 | Dupont | 500 | .4555 | Springfield, 3 grooved, 1/16 tin, solid-head shell. | 6 | 2.8 | 6.9 | 7.4 |
| Do | 70 | ....do | 500 | .4555 | ......do | 7 | 5.3 | 5.4 | 7.6 |
| Do | 70 | ....do | 500 | .4555 | ......do | 8 | 5.7 | 5.6 | 8 |
| Do | 70 | ....do | 500 | .4555 | ......do | 9 | 4.3 | 6.4 | 7.7 |
| Do | 70 | ....do | 500 | .4555 | ......do | 10 | 4.9 | 6.6 | 8.2 |
| | | | | | Calm. | Mean. | 5 | 6 | 7.9 |
| Oct. 19, 1880. | | | | | | | | | |
| Service | 70 | Dupont | 500 | .4555 | Springfield, 3 grooved, 1/16 tin, solid-head shell. | 1 | 4.8 | 3.1 | 5.7 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 8.3 | 6.2 | 10.4 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 6 | 3.1 | 6.8 |
| Do | 70 | ....do | 500 | .4555 | ......do | 4 | 3.2 | 3.1 | 4.4 |
| Do | 70 | ....do | 500 | .4555 | ......do | 5 | 6.5 | 7.1 | 9.6 |
| Do | 70 | ....do | 500 | .4555 | ......do | 6 | 3.7 | 7.1 | 8 |
| Do | 70 | ....do | 500 | .4555 | ......do | 7 | 6.8 | 7.2 | 9.9 |
| Do | 70 | ....do | 500 | .4555 | ......do | 8 | 5.1 | 4.4 | 7 |
| Do | 70 | ....do | 500 | .4555 | ......do | 9 | 4.9 | 4.7 | 6.8 |
| Do | 70 | ....do | 500 | .4555 | ......do | 10 | 5.7 | 4.8 | 7.5 |
| Light breeze | from the right. | | | | | Mean. | 5.5 | 5.1 | 7.6 |

300 *yards range.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M.H. | Deviations. M.V. | Deviations. M.A. |
|---|---|---|---|---|---|---|---|---|---|
| Oct. 22, 1880. | *Grs.* | | *Grs.* | | | | | | |
| Service | 70 | Dupont | 500 | .4555 | Springfield, 3 grooved, 1/16 tin, solid-head shell. | 1 | 2.2 | 3.3 | 4 |
| Do | 70 | ....do | 500 | .4555 | ......do | 2 | 3 | 3.8 | 4.8 |
| Do | 70 | ....do | 500 | .4555 | ......do | 3 | 3 | 2.9 | 4.2 |
| Do | 70 | ....do | 500 | .4555 | ......do | 4 | 2.6 | 2.8 | 3.8 |
| Do | 70 | ....do | 500 | .4555 | ......do | 5 | 2.8 | 2.4 | 3.7 |
| Do | 70 | ....do | 500 | .4555 | ......do | 6 | 2.8 | 2.8 | 4 |
| Do | 70 | ....do | 500 | .4555 | ......do | 7 | 2.7 | 3.4 | 4.3 |
| Do | 70 | ....do | 500 | .4555 | ......do | 8 | 3.5 | 3.5 | 4.9 |
| Do | 70 | ....do | 500 | .4555 | ......do | 9 | 2.2 | 3.9 | 4.5 |
| Do | 70 | ....do | 500 | .4555 | ......do | 10 | 2.4 | 3.4 | 4.2 |
| | | | | | | Mean. | 2.7 | 3.2 | 4.2 |

Fresh breeze from left and front; dark and rainy.

FRANKFORD ARSENAL, *October* 23, 1880.

To the COMMANDING OFFICER, *Frankford Arsenal:*

SIR: I have the honor to report, in compliance with your orders, the execution of the following programme:

*Subject of experiment:*

"Long-range cartridges from the National Armory."

*Object of experiment:*

"To compare their accuracy with service cartridge."

*The arms:*

"Service rifle and Springfield long-chambered rifle."

*The ammunition:*

"*W.* 100 solid-head outside-primed cartridges, 80 grains powder, 500-grain bullet."

"*B.* 100 folded-head, 70 grains powder, 500-grain bullet."

"*Y.* 75 solid-head, 70 grains powder, 500-grain bullet."

"*A.* Service folded-head, 70 grains powder, 405-grain bullet."

*The rest:*

"Fixed."

*The range:*

"500 yards."

*The firing:*

"Six targets of 10 shots each of W, B, Y, and A, alternately in the order given, taking two sighting shots for each target, and cleaning gun after each target is made. W to be fired from the Springfield long-chambered rifle, and B, Y, and A from the service rifle.

"The firing to be commenced upon the first suitable day, eliminating so far as possible all adverse meteorological conditions, such as wind, &c.

"The results to be reported in accordance with the last instructions from the Chief of Ordnance."

The above directions were carried out on the 19th instant, under very favorable weather conditions. The day was bright and clear; a slight breeze made itself felt, varying, during the progress of the firing, between 3.30 and 4.30.

The cartridges received from Springfield were marked "Hazard, F. G. powder No. 3," "Bullet $\frac{1}{16}$ tin."

The bullets were apparently swaged in a solid die and were highly polished.

All the cases fired were Frankford Arsenal manufacture, except for the 5th and 6th W targets, which were made by Winchester cases. The "radius of circle of shots" and the "distance from point aimed at to center of shots" are given in subjoined table, and are also arithmetically and graphically represented on accompanying sheet, which depicts the actual targets on a $\frac{1}{48}$ scale.

In sighting, elevation alone was taken into consideration, and the slide was raised to 450 yards for the W and A targets, and to 500 yards for the B and Y targets.

Very respectfully, your obedient servant,

O. E. MICHAELIS,
*Captain of Ordnance, in charge of Firing.*

Approved:
S. C. LYFORD,
*Major of Ordnance, Commanding.*

*Comparison of accuracy of cartridges received from National Armory, and daily work.—Range* 500 *yards.*

| Series. | W. 80 grains powder, 500-grain bullet, folded-head. | | B. 70 grains powder, 500-grain bullet, folded-head. | | Y. 70 grains powder, 500-grain bullet, solid-head. | | A. 70 grains powder, 405-grain bullet, folded-head—Service. | |
|---|---|---|---|---|---|---|---|---|
| No. | Radius of circle of shots. | Distance from point aimed at to center of shots. | Radius of circle of shots. | Distance from point aimed at to center of shots. | Radius of circle of shots. | Distance from point aimed at to center of shots. | Radius of circle of shots. | Distance from point aimed at to center of shots. |
| | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* |
| A...... | .800 | 2.300 | .820 | 2.550 | .775 | 1.050 | .977 | 2.700 |
| B...... | .665 | 2.920 | .550 | 1.130 | .587 | 1.280 | .870 | 3.500 |
| C...... | .666 | 3.300 | .860 | 2.100 | .660 | 3.500 | .825 | 2.600 |
| D...... | .640 | 2.170 | .740 | 1.760 | .645 | 2.400 | .775 | 2.250 |
| E...... | *.760 | 2.660 | .900 | 1.750 | .580 | .750 | .645 | ............ |
| F...... | *.280 | 2.350 | .590 | 1.500 | .810 | 2.100 | .796 | 1.430 |
| Mean.. | .635 | 2.617 | .743 | 1.798 | .676 | 1.847 | .815 | 2.350 |

* Brass.

Approved:
S. C. LYFORD,
*Major of Ordnance, Commanding.*

NATIONAL ARMORY,
*Springfield, Mass., October 30, 1880.*

SIR: Your letter of the 28th instant relating to certain lubricants for the service-rifle projectile is received. I inclose herewith the results of firings made at this armory by Captain Greer, to determine the relative merits of Japan wax and bees-wax and sperm oil, as regards accuracy of fire. The results, it will be observed, are slightly in favor of the bees-wax and sperm oil; the difference, however, is so slight that the two lubricants may be considered practically equal in this respect. In view of this and the fact that Japan wax is known to be unaffected by ordinary changes of temperature and does not act injuriously on the powder, bullet, or cartridge shell, I recommend that its use be continued until something better is found as a substitute.

Very respectfully, your obedient servant,

J. G. BENTON,
*Colonel of Ordnance, Commanding.*

CHIEF OF ORDNANCE U. S. A.,
*Washington, D. C.*

800 *yards range.*

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | M.H. | M.V. | M.A. |
| | *Grs.* | | *Grs.* | | | | | | |
| Service, long-chamber. | 80 | Hazard, F. G.. | 500 | .458 | Frankford, Japan wax lubricant. | 1 | 14.2 | 13.1 | 19.3 |
| Do | 80 | ....do | 500 | .458 | ......do | 2 | 12.7 | 16.9 | 21.1 |
| Do | 80 | ....do | 500 | .458 | ......do | 3 | 13.2 | 14.6 | 19.7 |
| Do | 80 | ....do | 500 | .458 | ......do | 4 | 8.4 | 19.4 | 21.2 |
| Do | 80 | ....do | 500 | .458 | ......do | 5 | 12.7 | 21.3 | 24.8 |
| | | | | | | Mean.. | 12.2 | 17.1 | 21.2 |
| Do | 80 | ....do | 500 | .458 | Frankford, bees-wax and sperm oil lubricant. | 1 | 4.6 | 15.6 | 16.3 |
| Do | 80 | ....do | 500 | .458 | ......do | 2 | 8.8 | 17.1 | 19.2 |
| Do | 80 | ....do | 500 | .458 | ......do | 3 | 8.1 | 15.1 | 19.8 |
| Do | 80 | ....do | 500 | .458 | ......do | 4 | 8.7 | 20.5 | 22.3 |
| Do | 80 | ....do | 500 | .458 | ......do | 5 | 8. | 17.4 | 19.1 |
| | | | | | | Mean.. | 7.7 | 19.1 | 19.3 |

500 *yards range.*

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | M.H. | M.V. | M.A. |
| | *Grs.* | | *Grs.* | | | | | | |
| Service | 70 | Hazard, F. G.. | 505 | .4555 | Springfield, 2 grooved, solid-head shell, Japan wax. | 5 | ...... | ...... | 9.2 |
| Do | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, folded-head shell, Japan wax. | 5 | ...... | ...... | 11.8 |
| Do | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, solid-head shell, sperm oil and bees-wax. | 10 | ...... | ...... | 7.9 |
| Do | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, folded-head shell, sperm oil and bees-wax. | 10 | ...... | ...... | 11.3 |

1,000 *yards range.*

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | M.H. | M.V. | M.A. |
| | *Grs.* | | *Grs.* | | | | | | |
| Service | 70 | Hazard, F. G. | 505 | .4555 | Springfield, 2 grooved, solid-head shell, Japan wax. | 4 | ...... | ...... | 28. |
| Do | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, folded-head shell, Japan wax. | 3 | ...... | ...... | 324 |
| Do | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, solid-head shell, sperm oil and bees-wax. | 12 | ...... | ...... | 29.2 |
| Do | 70 | ....do | 505 | .4555 | Springfield, 2 grooved, folded-head shell, sperm oil and bees-wax. | 12 | ...... | ...... | 29.6 |

# APPENDIX 18.

## REPORT ON A TELEMETER-SIGHT INVENTED BY CAPT. LUIGÉ FOLTA, ITALIAN ARTILLERY, BY CAPT. JOHN E. GREER, UNDER THE DIRECTION OF COL. JAMES G. BENTON, ORDNANCE DEPARTMENT.

(One plate.)

NATIONAL ARMORY,
*Springfield, Mass., November* 17, 1880.

SIR: In accordance with your instructions to examine and test the telemeter-sight, invented by Capt. Luigé Folta, Italian artillery, and brought to the notice of the Chief of Ordnance by Lieutenant Russel, Ordnance Department, I have the honor to submit the following report:

The meager description accompanying this sight briefly details its operation and mechanical construction, but gives no information as to the principles on which its construction is based. It states simply that the spiral curve on the cylindrical stem which governs the motion of the stadium slide is of variable, while that which operates the rear sight is of uniform twist. As by construction the determination of the distance of an object by the stadium is intended to set the rear sight for that distance, it is evident that some relation must exist between the height of the rear sight and the range, also between the height of the opening in the stadium and the range, and that by their combination the desired result is produced.

In the absence, therefore, of information as to the mental process of the inventor, on which its construction depended, it is proposed to discuss briefly

### THE THEORY OF THE SIGHT.

I. To find the relation between the height of the rear sight and the range.

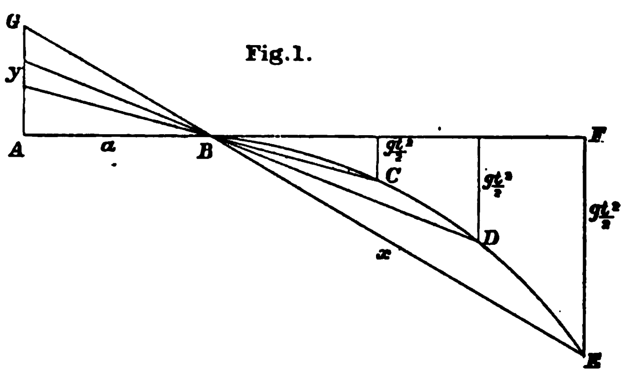



Fig. 1.

Let A B = $a$ be the axis of the bore between sights, B C D E a portion of the trajectory, and $y$ the height of rear sight for any range $x$. If we draw a straight line through the point aimed at, as E, and the point B on the axis below the front sight (neglecting the height of the sight, since it serves merely to increase that of the rear sight by a sensibly equal amount), we shall have the line

of sight. This line, if prolonged, will intersect the rear-sight leaf at the point at which the slide should be set to reach the object.

From this we have $y : a :: \text{F E} : \text{B F}$. But $\text{F E} = \frac{gt^2}{2}$,

and $\text{B F} = \sqrt{x^2 - \left(\frac{gt^2}{2}\right)^2}$. Substituting, we have

$$y : a :: \frac{gt^2}{2} : \sqrt{x^2 - \left(\frac{gt^2}{2}\right)^2}; \therefore y = \frac{agt^2}{\sqrt{4x^2 - g^2t^4}} = \frac{a}{\sqrt{\frac{4x^2}{g^2t^4} - 1}}$$

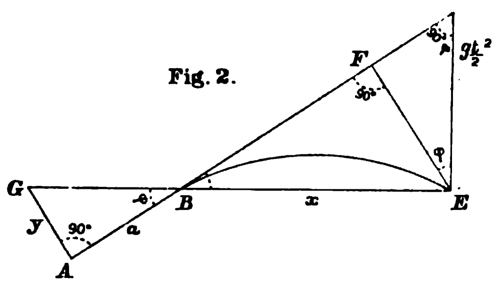
$\frac{4x^2}{g^2t^4}$ is so great, however, in comparison with unity, that the latter may be omitted from the denominator of the second member of the preceding equation without material error, when

$$y = \frac{a}{\sqrt{\frac{4x^2}{g^2t^4}}} = \frac{a_1gt^2}{2x^1}. \quad (1.)$$

But $t$ increases more rapidly than the range $x$ because of the diminution of the bullet's velocity; the numerator of the second member therefore increases more rapidly than the square, while the denominator increases as the first power of $x$; *hence $y$ increases more rapidly than the range.* The curve to be cut on the stem for operating the rear sight *should not, therefore, be of uniform, but decreasing twist.* (See Fig. 7.) Again, $t = \frac{2x}{v + v^1}$ nearly, $v$ being the initial and $v^1$ the remaining velocity at any point; substituting and reducing, we have $y = \frac{2agx}{(v + v^1)^2}$. (2.)

The above, of course, is true only when the axis of the bore is horizontal, $\frac{gt^2}{2}$ then being perpendicular to it. As the axis makes an angle greater and greater with the horizontal the greater the error. The angle, however, for a range of 1,000 yards being less than 3° the error is very slight. Should the elevation be very great,

Fig. 2.




$\frac{gt^2}{2}$ should be multiplied by the sine of 90° minus the angle of elevation, as appears from Fig. 2, since $\text{F E} = \frac{gt^2}{2}$ sin. $(90° - \varphi.)$

The curve of which (1) is the equation may be constructed when $t$—which may be determined experimentally by the Schultz chronoscope or by means of a telephone and stop-watch, or conveniently by Didion's formula, page 417, Benton's Ordnance and Gunnery, for the various ranges—is known. Equation (2) may be used if preferred, $v^1$ being determined by Noble's, Bashforth's, or Didion's formula.

The following values of $y$ were determined from equation (2), $v^1$ having been found for the various ranges:

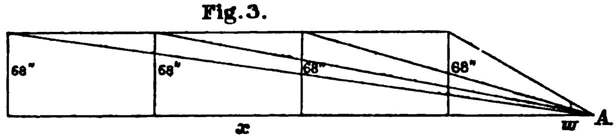
TABLE I.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $x$ | 100 yds. | 200 yds. | 300 yds. | 400 yds. | 500 yds. | 600 yds. | 700 yds. | 800 yds. | 900 yds. | 1, 000 yds. |
| $y$ | 0″.085 | 0″.188 | 0″.312 | 0″.451 | 0″.602 | 0″.766 | 0″.941 | 1″.125 | 1″.318 | 1″.519 |

From these values of $x$ and $y$ the curve may be constructed. If this curve be cut on the stem that carries both stadium and rear sight, and the ranges corresponding to the different values of $y$ be entered on the hollow cylinder inclosing the stem, the sight may be adjusted to any range by simply rotating the stem about its axis, raising or lowering the sight until it is at the required point.

II. To find the relation between the range and the height of the opening in the stadium.

Fig. 3.




Let $x$, Fig. 3, be the range in inches; $w$ the height in inches of the opening in the stadium for the range $x$; A be the position of the eye 15″.75 from the stadium, and 68″ be assumed as the average height of the soldier.

From the figure we have $68'' : w :: x : 15''.75$; $\therefore w = \frac{1071}{x}$.

If we assign values to $x$ of 100, 200, 300, &c., yards, the corresponding values of $w$ may be determined as in

TABLE II.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $x$ | 100 yds. | 200 yds. | 300 yds. | 400 yds. | 500 yds. | 600 yds. | 700 yds. | 800 yds. | 900 yds. | 1, 000 yds. |
| $w$ | 0″.2975 | 0″.1487 | 0″.0992 | 0″.0744 | 0″.0595 | 0″.0496 | 0″.0425 | 0″.0372 | 0″.0331 | 0″.0297. |

As these values of $w$ were deduced under the assumption that the soldier is 68 inches in height, it is evident that they cannot be absolutely correct for any other height. It is, therefore, necessary to ascertain what variation in height of opening may be produced by varying the height of the soldier, say 4 inches, since very few men exceed 6 feet or are below 5 feet 4 inches in height.

Substituting 72″ for 68″ in the proportion first given, and proceeding as before, we have

TABLE III.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $x$ | 100 yds. | 200 yds. | 300 yds. | 400 yds. | 500 yds. | 600 yds. | 700 yds. | 800 yds. | 900 yds. | 1, 000 yds. |
| $w$ | 0″.315 | 0″.157 | 0″.105 | 0″.079 | 0″.063 | 0″.053 | 0″.047 | 0″.039 | 0″.035 | 0″.0315 |

Comparing this with the preceding table, we see that the difference in the values of $w$ for the same range is very slight, and yet the accuracy

of the instrument is somewhat affected, as explained later on, particularly at the longer ranges.

III. To determine the curve to be cut on the stem for governing the motion of the stadium.

Fig. 4.

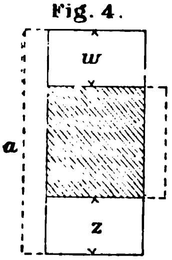
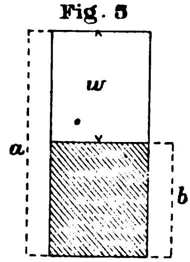



Fig. 5

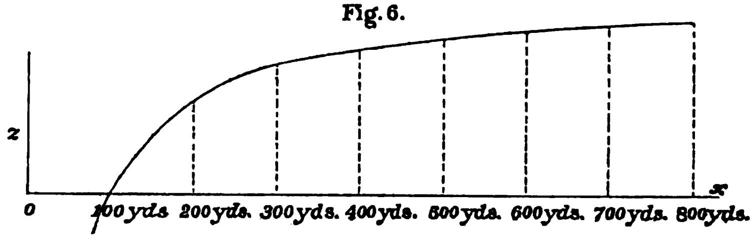



Let $a$ represent the height of the sight frame; $b$, that of the stadium slide; $w$, that of the opening in the stadium as before; and $z$, the variable distance from the bottom of the slide to that of the frame.

From Fig. 4 we have $z=a-b-w$.

As the slide is at its lowest point when set for a range of 100 yards, $z=0$ at that range, and Fig. 5, $a-b=w=0''.2975$, Table II; hence we have $z=0''.2975-w$, which is the equation of a curve with an increasing twist, the axis of $z$ being an asymptote to it. (See Fig. 6.)

Fig. 6.




Now by construction the bar which limits the opening in the stadium from above is a part of the rear sight and therefore rises through a height corresponding to an increase of range when the sight is adjusted for that range. The stadium slide must therefore ascend the same height plus the additional height necessary to reduce the opening in the stadium to that corresponding to the range. That is, if the rear sight be raised to a height $y$ for any range the stadium slide will be raised to a height $y+z$, and we shall have for the equation of the desired curve—

$$y+z=\frac{agt^2}{2x}+0''.2975-w. \quad (3.)$$

Substituting for $\frac{agt^2}{2x}$ and $w$ their values previously deduced, Tables I and II, for ranges of 100, 200, &c., yards, we have the following table of values for $y+z$, the ordinate of the curve at its various points:

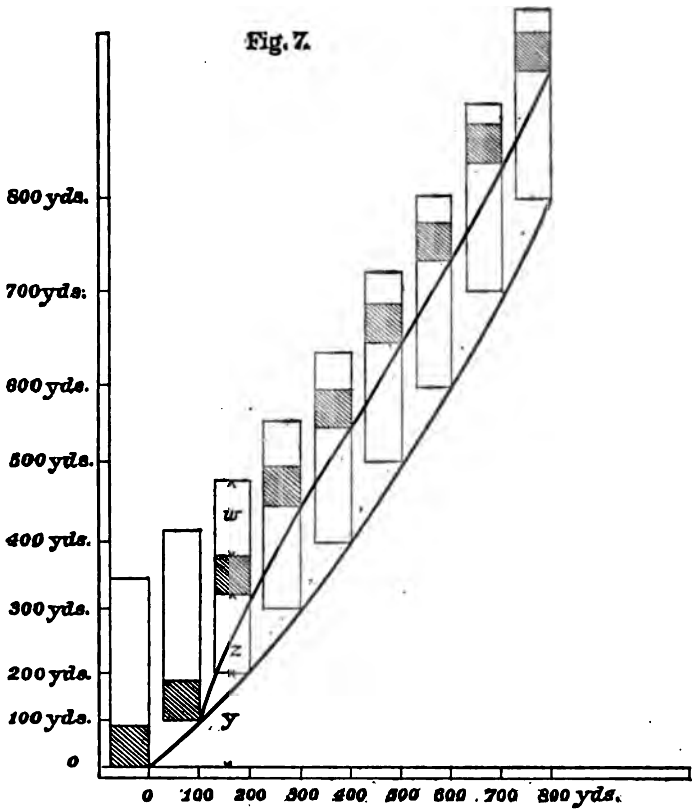
TABLE IV.

| $x$ | 100 yds. | 200 yds. | 300 yds. | 400 yds. | 500 yds. | 600 yds. | 700 yds. | 800 yds. | 900 yds. | 1,000 yds. |
|---|---|---|---|---|---|---|---|---|---|---|
| $y+z$ | 0''.085 | 0''.337 | 0''.51 | 0''.674 | 0''.84 | 1''.014 | 1''.196 | 1''.385 | 1''.582 | 1''.787 |

The curves of which (1) and (3) are the equations, and their action with reference to sight and stadium, are shown in Fig. 7; the horizontal scale being 0''.4 to 100 yards and the vertical four times natural size. The sight and stadium are assumed at pleasure. The vertical scale at the left also shows graphically how the height of the rear sight increases as the range increases.

The abrupt change in the developed curve that operates the slide is due to the arbitrary setting of the slide at its lowest point for a range of 100 yards.

Fig. 7.




## TESTS.

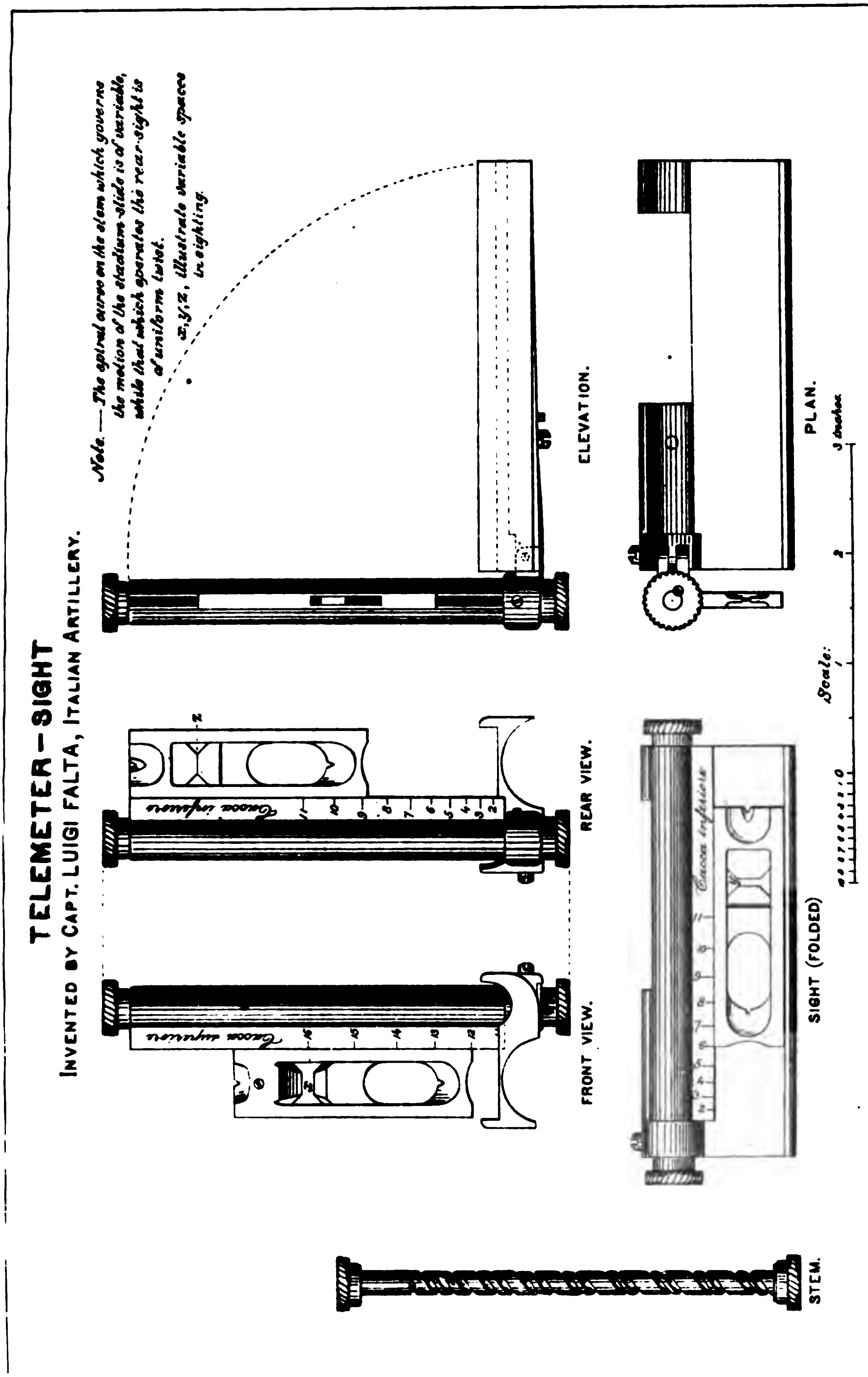
In order to test the telemeter-sight a peep-sight was prepared like that shown in the drawing. A man 68 inches in height was then placed in front of the 100 yards target and the sight carefully adjusted by a skilled marksman, Mr. R. T. Hare, of this armory—a muzzle rest being used—to take in his entire height, after which the height of the opening in the stadium was carefully measured in order to compare it with that already found by computation in Table II. This was repeated at the 200, 300, 500, 600, and 800 yards targets with the results given in—

TABLE V.

| $x$ | 100 yds. | 200 yds. | 300 yds. | 500 yds. | 600 yds. | 800 yds. |
|---|---|---|---|---|---|---|
| $y$ | 0″.32 | 0″.16 | 0″.11 | 0″.06 | 0″.065 | 0″.03 |

These values of $y$, while differing but little from those in Table II, correspond to ranges of 93, 186, 270, 496, 458, and 992 yards, respect-

ively. From this it will be seen that the slight error in determining the height of the opening at the longer ranges will cause a very great error in the range itself; for instance, at 800 yards the height found experimentally differed by but 0''.007 from the true height, and yet the indicated range was 992 yards. This is shown graphically in Fig. 5, there being no sensible difference in the height of the ordinates for ranges above 400 yards. For the purpose of correcting as far as possible this extreme delicacy the distance between eye and stadium should be as great as possible, as the difference between any two heights of the opening would be greater; in other words, the telemeter should be near the muzzle and hence separate from the rear sight. It would also be advisable to separate the sight from the telemeter on the score of economy and weight independently of the reason first given. Finally, the construction of the stadium is such that the blur in sighting at a man, unless very near, causes a great straining of the eye to take him in even when standing motionless, which is rather more than we can reasonably expect an enemy to do at ranges at which this sight can be used. It only remains to add that, having determined the distance in each case, the gun was fired, but with such extraordinary results as almost to lead one to believe the curves had been cut on the stem at random rather than as a result of computation. The rifle, however, having a different front sight and firing a different cartridge from that for which the telemeter-sight was intended, probably accounts for the great discrepancy between the indicated range and the graduation of the sight necessary to attain it. As a result of the trials and the facts above developed the conclusion is inevitable that this sight is more ingenious than useful.


TELEMETER - SIGHT
INVENTED BY CAPT. LUIGI FALTA, ITALIAN ARTILLERY.
Note.—The spiral curve on the stem which governs the motion of the stadium-slide is of variable, while that which operates the rear-sight is of uniform twist.
x, y, z, illustrate variable spaces in sighting.
ELEVATION.
PLAN.
FRONT VIEW.
REAR VIEW.
SIGHT (FOLDED)
STEM.
Scale:
3 Inches

# APPENDIX 19.

## REPORT ON THE INSPECTION OF CONTRACT SMALL-ARM AMMUNITION BY CAPT. HENRY METCALFE, ORDNANCE DEPARTMENT.

(Three plates.)

SIR: I have the honor to submit herewith an account of the manner of inspecting contract rifle-ball cartridges, and of the tools and instruments used in the inspection.

The inspection is governed by the following general principles:

I. For convenience, distinctiveness, and to restrict the risk, the cartridges are inspected in definite quantities, called "lots," from each of which a certain proportion is taken at random and carefully fired, gauged, and viewed. Among these, according to the gravity of the defect, a certain number of imperfections are allowed (see form of contract appended). In case this number is exceeded, the contractor is afforded an opportunity of weeding out the bad work before the final inspection is made. In the final inspection the proportion of allowable defects is reduced one-half.

The practical result of this method is to induce the contractor to take great care with his own preliminary inspection, so that the official inspection may serve merely to verify work which should have already been performed. It should not be the duty of the inspector to cull good work from the bad; his province is to see that this has already been done, or to require it under penalty.

It will be observed hereafter that no provision is made for marking or withholding rejected work. The presumption is that bad work cannot be intentionally mixed with good without involving too great a risk to make the enterprise profitable.

II. The cartridges are judged, as far as possible, by their actual performance while firing in a rifle of prescribed dimensions.

The best result would be obtained could this firing be conducted so as to include a trial of accuracy, which is of necessity the supreme test of all ammunition.

But as this course would involve many conditions which could not be allowed for without serious doubt or dissension, it is deemed better to infer the accuracy from the corresponding uniformity of the initial velocity. This can be readily prescribed and exactly determined without reference to person, place, or time; while the reputation of the manufacturer in the field may be safely trusted to provide those refinements of workmanship upon which great accuracy depends.

III. The firing is supplemented by gauging only so far as may be required to make sure that the cartridges will enter any gun in service and be certainly extracted from it, and also to establish a necessary inference as to their keeping qualities.

IV. The gauges should represent, as far as possible, the actual surroundings of the cartridge while in the gun. They should be simple in construction and application, and few in number. Where they are meant to establish allowable variations from a standard, the differences

of each pair, or the "limits," should be set as far apart as may be consistent with the requirements of the preceding paragraph.

This will lessen the cost of purchase as well as of production by diminishing the waste; help the ordinary inspection directly, besides facilitating the attainment of the complete mechanical inspection of every cartridge made; avoid causes of contention, and, by considering as immutable only those conditions pertaining to the gun, open the way for improvements in the more easily altered cartridge.

The contractor will be wise to make his working gauges for shop use a little smaller than the maximum and a little larger than the minimum gauges, so as to allow for wear, dirt, and unavoidable differences of manufacture. This should be considered in setting the limits.

V. The gauges once set should be rigidly adhered to; since from the nature of the inspection as hereafter explained, no discretion should be allowed to subordinates except as to questions of workmanship, &c. If occasion should require it, the limits should be changed by the proper authority, but no allowance outside of them should ever be taken by a sub-inspector. Otherwise his responsibility ceases, for verification of his work becomes impossible.

Dimensions which are known to be permanent also assist in determining the causes of failures in service, which may be due to the gun instead of to the cartridge.

The inspection may be continuous, as by one or more resident sub-inspectors, or by visits from the officer in charge of the work. In either case the principles are the same, the differences relating more to the size of the "lots" inspected and to the discretion taken in original questions. The size of the lots will vary according to the size of the contract. Where there is but one resident sub-inspector 10,000 cartridges may well form a lot. When inspected by an officer, as above, 10 lots or 100,000 cartridges are about the number justifying a visit. In large contracts, as in the Turkish contract, the lots were of 50,000 cartridges, requiring several sub-inspectors under an inspector in charge of each factory. Where several factories are engaged, they are united under a principal inspector.

Assuming that the inspection is by visit from the officer in charge of the work, its practical course is as follows:

One or more lots—say 10 lots of 10,000 cartridges each—having been reported by the contractors as ready for inspection, one case in each lot is opened by the inspector and 200 cartridges taken from it. To facilitate this, the different lots are numbered outside of the cases in which they are packed, and piled separately, with the lids only temporarily secured.

The inspector can thus readily designate a certain case in each lot and direct the removal of any certain layer from it. Each paper package is marked with the number of the lot on one end of the body near the lower edge of the lid.

These packages having been secured in the inspecting room to await further action, two or more packages of each lot are marked and taken to the firing-room.

There one package from each lot is fired from a rifle worn so as to fairly represent an arm which has seen considerable service. This is known as the standard rifle. It should be gauged in the mouth of the chamber and the counterbore space from time to time, so as to make sure that it does not exceed the prescribed dimensions. So for the firing-pin, which should work freely and project the prescribed distance.

This firing is to test the working of the ammunition as to strength

and certainty of fire and of extraction. As the empty shells of each lot fall to the ground they are gathered into a small pan, into which is thrown the empty pasteboard package marked with the number of the lot as a means of identification.

This box, going by the name, for want of a better one, of the "hospital," serves to contain in its compartments all doubtful or defective cartridges for the inspection which now takes place for pierced or leaky primers, and for split, burst, or very dirty shells.

A leaky primer is accounted one in which the fouling has discolored the head of the cartridge beyond the primer pocket. Small specks of fouling close to the primer do no harm. The danger to be guarded against is the fouling of the firing-pin hole. A pierced primer is a more serious matter, as the erosive force of the jet of gas is very destructive.

The longitudinal splitting of a cartridge is much less serious than a transverse burst or tear.

The fouling back of the case outside is often caused by dampness remaining in the chamber after cleaning the gun.

To constitute a serious defect the fouling should run back to the head, indicating a likelihood of gas escape outside the arm, which might injure the firer.

A failure to extract may occur from the softness or thinness of the edge of the flange, undiscoverable by the ordinary process of gauging, combined with unusual resistance to extraction, such as fouling, &c., within the chamber.

The trouble is also sometimes due to the extractor. In the early manufactures of the rifle this occasionally became worn so that the point would rise higher than was intended.

The cartridge-head, particularly if small or a little eccentric, might pass under or beside the extractor and be shorn from rear to front in closing the breech-block. It might also catch against the sharp point of the extractor so as to crowd the cartridge against the opposite edge of the chamber in entering, frequently giving the impression thereby that the cartridge was unduly large in the body or the head.

Should a cartridge slip by, the cause of the failure should be ascertained, as this constitutes a serious defect.

Causes of misfires should be discovered.

Each defect as it is discovered is designated on the side of the box opposite to the compartment in which the shell is put. All shells meeting the requirements are thrown into the scrap barrel and are no longer considered.

Besides the firing done from the standard rifle, which alone decides this part of the inspection, it is well to fire now and then a package from the Hotchkiss and Gatling guns, maximum or minimum service rifles representing the most worn and tightest-fitting guns that can be found, and any other special arms concerning the adaptability of the ammunition to which information may be valuable. The firing from the machine guns should be done with the utmost rapidity.

This firing has nothing to do with the acceptability of the cartridges under the contract, although the result of it goes on the inspection report.

Firing should be done as much as possible by the inspector himself, and from the shoulder.

If the cartridges are reloading, ten should be taken now and then from some lot and reloaded and fired five times. Not more than one cartridge should burst or split in so doing. (See contract hereafter.)

It is well also for information to do the re-firing occasionally in the maximum and minimum guns alternately with and without resizing.

All failures should be put into the hospital boxes and marked, so as to be accounted for on the inspection report.

The firing for initial velocity may now be conducted, running all ten lots through at once, by firing five shots out of the second package above referred to.

It is advisable to fire at the beginning, middle, and end of the series a few, say 10, service cartridges of known initial velocity. The difference between the average results indicated by the chronograph and the velocities marked on the service ammunition will give a $\pm$ correction which should be applied to the indicated velocities of the contract cartridges.

For example: If the service ammunition which is marked "IV—1,330 feet" should give at the factory an indicated velocity of 1,325 feet at the same time that the inspected work gave 1,316 feet, the true velocity of the latter to be entered on the inspection report would be 1,321 feet.

This course corrects all constant instrumental errors and those of position, excepting such as may be irregular in their nature. Among these are passing wagons and trains, the starting of trip-hammers or other vibratory machinery, or the *cessation* of these disturbances.

When convenient, it is well to confine this firing to the dinner hour.

To insure the stability of the chronographic apparatus against the shock of the discharge, experience has shown that it may be well to place the instrument *beyond* the second target and to establish communication with the firing point through a telephone.

A very good instrument for this purpose can be bought for $5. The signal can be given by tapping on the diaphragm.

The Le Boulengé chronograph, on account of its portability, is probably the best instrument for inspecting. It works well if carefully adjusted in its mechanical points.

It should be mounted on an independent pedestal. A block of wood sunk into the ground without touching the surrounding floor answers very well.

The rods and electro-magnets should be tested every now and then for resistance, insulation, and permanent magnetism. The resistance of the coils should be about 10 ohms. Defective insulation, due to the burning effect of lightning or to the accidental transmission of too intense a current, can be detected by the quivering of the galvanometer needle while testing the resistance.

The zinc cylinders are very conveniently blackened by dipping them for a moment in an acid solution of sulphate of copper (old cartridge pickle), and then rinsing and wiping them inside and out. By this means they can be used over and over again, as the knife makes a clear bright cut without spawling.

Each shot can be numbered with a lead pencil or a sharp metallic point.

It is well before beginning the series to mark a line around the tube at the standard velocity desired, say 1,325 feet, or else at the velocity limits.

The eye alone can thus judge very closely of the result without stopping to measure at every shot. We not only thus save time, but the results are obtained under more closely similar conditions, and mistakes of measurement are less likely to occur when the cuts are all measured in immediate succession at the end of the firing.

In case any extraordinary velocity is recorded it can be more readily detected. It is well in such a case to take immediately a few disjunctions, and if the instrument and the second target appear all right, to

draw a few of the bullets from the remaining cartridges and examine and weigh the charges.

The variation in weight of bullets is prescribed. The extreme variation in weight of ten powder charges should not exceed a grain nor the mean variation one-quarter grain. Under ordinary circumstances the variation of a grain in the weight of powder corresponds to about 8 or 10 feet in velocity.

The weighing is only to confirm the indications of the chronograph and to direct special attention to the cause of the defect. The result of the firing is decided by the chronograph unless it can be shown to be wrong.

When the chronograph is in good working order, a disjunction every five shots, or between lots, is sufficient for all practical purposes.

The gun should be wiped every five shots and occasionally examined for leading. Since wiping out the gun, especially with water, has a tendency to lower the velocity of the next succeeding cartridge, it is well when this course is followed to fire six shots and discard the first of the series.

When time presses and assistance can easily be had, the firing for velocity can be greatly expedited by having three helpers. The inspector being at the chronograph, one helper—a boy will do—to work the disjunctor close at hand; a second to fire; a third to wipe out the gun and mend the first target; and if possible a fourth to watch the second target screws and keep them from jarring loose. With three helpers three velocities per minute can easily be taken.

The single strand of fine copper wire with a ratchet tension answers best for the first target [Plate I.]

For the second target an iron or steel plate about 12″ by 12″ by 1″.5, secured between two uprights and with a spring circuit-breaker behind it, as shown in Plate I, answers best for this kind of work, in which rapidity rather than extreme accuracy is required. This is the arrangement devised at this arsenal by Capt. William Prince, Ordnance Department, and in use here for several years.

Owing to the tremendous energy of the bullet's impact, about 0.8 foot-ton, the spring is sometimes deranged, or set so that its contact with the breaking point is altered. This sometimes changes the electrical resistance at that point, causing a variation in the next disjunction record or affecting the value of the next shot.

It should be tested by snapping the spring with the finger between several successive disjunctions.*

The shock is also sometimes apt to loosen the target wires and produce the same result. For this reason it is well to connect the line wires to short pieces of wire soldered fast to the electrical fittings of the second target, as shown in Plate I.

Long-continued firing is also apt to extend in a convexed form the face of the iron plate, so that the wooden backing will only bear at its ends and thus receive the shock less readily.

For these reasons it is well to examine the second target frequently during the firing, and as the inspector is generally at the chronograph, the target should, as already suggested, be readily accessible from the building in which this is placed. This is more important than it may seem, for the second target being a mechanism is as much subject to derangement as the chronograph, and should be under the same control.

The fired shells are then examined as before prescribed, and, if accept-

* This may be corrected by limiting the excursion of the spring or the derangement of its support by suitable mechanical means.

able, the gauging may begin. But if the allowable number of defects should have been exceeded, the lot can be at once returned to the contractor for re-examination; or if desired for his more complete information, the guaging may be proceeded with, according as time or expediency may direct.

Ten shots from each lot should be fired for accuracy either at the factory or at some convenient arsenal. The firing should be done in comparison with service ammunition, as in taking velocities.

The range usually selected is 500 yards, at which distance the mean deviation should not exceed one and a half times that of the service ammunition, nor the elevation $=\Phi$ be much greater.

By analyzing excessive differences, should they occur, the causes of variation may be discovered and reported to the contractor for correction.

Although 500 yards is probably the best range when it can be conveniently obtained, a much shorter range, even one of 40 yards, if frequently used may be of great assistance to the manufacturer, upon whom should be impressed the importance of constantly proving the result of his efforts to combine uniformly the different elements of the cartridge.

The single one of powder is subject to so many conditions of moisture, age, compression, &c., affecting its velocity, pressure, and fouling, that no safe conclusion as to its final performance can be reached, unless that performance be as closely imitated during the manufacture as can possibly be done.

The following are the nominal dimensions of the inspecting points. Their relations to the cartridge are shown in Plate III, in which maximum dimensions only, as the most important, are shown.

Work to be acceptable must enter or be entered by the proper maximum gauges, and must *not* enter or be entered by the proper minimum gauges.

| Dimensions of principal gauging points. | Standard. | Maximum. | Minimum. |
|---|---|---|---|
| Cartridge case— | | | |
| 1. Total length | 2''. 105 | 2''. 105 | .............. |
| 2. Diameter of cylinder inside | 0''. 458 | 0''. 458 | 0''. 458 |
| 3. Diameter of body at head | 0''. 505 | 0''. 505 | .............. |
| 4. Diameter of body at front | 0''. 480 | 0''. 480 | .............. |
| 5. Diameter of head | 0''. 610 | 0''. 610 | 0''. 595 |
| 6. Thickness of head | 0''. 070 | 0''. 070 | 0''. 065 |
| Bullet— | | | |
| 7. Diameter of cylindrical part | 0''. 458 | 0''. 458 | 0''. 458 |
| 8. Diameter of conical part in front of grooves | 0''. 445 | 0''. 447 | .............. |
| 9. Weight, grains | 405 | 407 | 403 |
| 10. Alloy—lead : tin :: 16 : 1. | | | |
| 11. Lubricant, Japan wax. | | | |
| Miscellaneous— | | | |
| 12. Total length of cartridge | 2''. 56 | 2''. 56 | .............. |
| 13. Charge of powder, grains | 70 | .............. | .............. |
| 14. Initial velocity, feet | 1,325 | 1,350 | 1,300 |

It will be observed that the minimum and internal dimensions are eschewed. The intention being, as expressed in Rule II, to allow the contractor to make his cartridges in his own way, provided surely that all will enter every gun, fire safely, and be extracted without fail. The firing is the surest and most conclusive guard against undue reduction in size.

For special reason requiring minima in Nos. 2 and 7 above see further on.

The external dimensions of the cartridge are expressed in terms of the standard inch in use at the National Armory, since these dimensions refer particularly to the adaptability of the cartridge to the arm; but the

dimensions of the bullet are in terms of the inch in use at this arsenal, where the bullets are made.

Although these differences are in course of correction by you by the adoption of a common standard, they are referred to so as to show the care taken to start rightly in the construction of the gauges, and to account for much of the vexatious dissension which has resulted in the inspection from neglecting these differences in standard. So, to prevent confusion by their comparison with different standard measures, all figured dimensions are omitted from the present inspecting gauges, which are made, however, as closely as possible of the same actual dimensions as certain holes and plugs adopted as the standard gauges.

The comparison is made by certain plugs, such as shown in Plate II, which are required to fit both the standard and the inspecting female gauges, and conversely.

Where the holes to be compared are taper, or where they terminate in shoulders against which a testing plug might abut, so as to give falsely the appearance of a fit, the holes are further tested by sectional plugs, shown at *b*, *c*, *d*, Plate II.

The extreme length of these plugs is the same as that of the standard plug *a*, but its surface is removed at all but the testing points. When dropped into a taper-hole, as into gauge No. 1, both ends should come flush with the ends of the gauge.

NOTE.—It takes less pressure to set these sectional plugs home, on account of their diminished bearing.

When it is considered that the taper of these gauges is 0''.505—0''.480 =0''.025 in 2''.035, or 0''.0010 in 0''.0814, it will be seen how closely the work has to be done to prevent the plug from projecting 0''.01, which would be an easily appreciable quantity to the touch, and yet represent a variation of less than *one-eighth* of one-thousandth of an inch in diameter.

NOTE.—A taper sectional gauge of this kind is very useful for examining the mouth of the gun-chamber, where the swelling of the cartridge is most apt to be felt. This was found particularly useful in the Turkish contracts, where the endurance of the shells was made a condition of their acceptance. In this case, owing to the peculiar construction of the reinforced Berdan shell, its endurance was much affected by the permanency of this dimension, the enlargement of which could not be discovered by ordinary plug gauges. So, also, the chamber of the gun—especially when of the bottle-necked pattern—might escape detection if enlarged about the middle, and yet cause cartridges fired in it to split or burst unfairly.

Although without especial reference to the gauges herein described, a costly experience has shown that it is well to adopt a similar precaution in making gauging holes for minimum dimensions.

The operation of grinding is inclined to render the hole somewhat flaring, so that a hole through which a standard plug may just pass may yet be large enough at the true measuring point—its mouth—to receive a cartridge one or two thousandths larger.

This is obviated in practice by turning out the inside of the hole, as shown in Plate II, Fig. *f*.

The concentricity and true depth of the counterbore of gauge No. 1 are proved by a plug, such as shown at *e*, Plate II. The solid button on the head of the plug should fill the counterbores of both the standard and the inspecting gauges in whichever way presented, and when in place it should turn freely in the gauge.

It may not be amiss to state here that the ordinary method of measur-

ing holes is first to make a plug to fit the hole, and then measuring the plug with a standard vernier, or, what is more exact, testing the fit of the plug in another standard hole. The hole itself is never measured where exactness is required. So with the length between shoulders.

The gauges shown in Plate I are those which I regard as essential for the examination of the selected specimen cartridges by the inspector. Their irregular numbering is due to their selection from a larger assortment, formed in the growth of the present system. The gauges omitted from consideration here are generally more valuable in the analysis of defects than in their discovery, and hence belong more to the province of the manufacturer than to the inspector.

*Gauge No.* 1 determines the maximum size of the body of the cartridge and its length, and the maximum *effective* diameter and thickness of the cartridge head. When a cartridge of the proper dimensions is in the gauge, no portion of the case should project from either end.

To test this a straight-edge is provided, which also serves to detect projecting primers. If the head should project it may be because the body is too large or crooked, or because the head is large or thick, or eccentric or oblique. The special fault may generally be found by turning the cartridge in the gauge and looking for the spot on which it rubs. This gauge should be tried on *every* cartridge inspected.

NOTE I.—Inasmuch as, owing to practical difficulties in hardening and grinding steel, it has been found almost impossible to make the counterbore of a hardened steel gauge exactly true with the body, it will be found advisable, in case a cartridge-head projects, to turn the cartridge until some position of the gauge is found in which it will enter, in consequence of the coincidence of the two eccentricities or obliquities.*

NOTE II.—In testing the projection of a doubtful head the cartridge should be pressed firmly home; but in testing the projection at the other end this action should be reversed and the cartridge pressed out to the rear until its head touches a straight-edge laid across the face of the guage, which in this case represents the face of the breech-block of a minimum gun.

NOTE III.—A very convenient form of this gauge, where constantly used, consists of a gauge as above described set in a frame provided with a turn-button sliding tightly over the face of the gauge. The frame is to be made fast to the edge of the work-bench.

*Gauge No.* 19. This measures the minimum eccentric diameter of head or double the minimum radius, which is the *effective* diameter of the head as far as its certainty of extraction is concerned. With the cartridge in place no portion of the shallow counterbore at the mouth of the gauge should be seen from above, nor for a stronger reason should the cartridge-head drop into the recess.

NOTE.—With folded-head cartridges, such as were formerly exclusively made, there is no necessity for the special feature of such gauges as Nos. 1 and 19, because the natural tendency of the sheet metal is to fold itself concentrically with the body of the case.

The metal of solid heads flows more irregularly, and they require closer inspection, even when trimmed by ordinary means.

*Gauge No.* 11.—This measures the maximum total length of the finished cartridge.

*Gauge No.* 14.—This gauge should slip over the point of the bullet down to the base of the conical part in the loaded cartridge, about to the mouth of the shell. Together with No. 11, its use prevents the con-

* This defect has been corrected in recent manufactures of counterbore gauges.

tact of a projecting or swollen bullet with the throat of the chamber and the consequent protrusion of the cartridge to the rear.

These gauges are required by the occasional starting forward of the bullet through an imperfect crimp in consequence of the expansion of the powder and air inside the case, or of its lateral swelling from undue compression in loading.

*Gauge No.* 12.—This measures the minimum thickness of head. No cartridge-head should enter the narrow notch in every position; that is, if it is refused in *some* position the presumption is that it was gauged thus on the preliminary inspection by the contractor, and that it should be accepted.

NOTE.—A gauge for this purpose may be made with a turn-button as described for No. 1, or a slide, only that the turn-button or slide should not close. The form adopted is more convenient and sufficiently exact for all practical purposes of inspection.

The other notch, giving the maximum thickness, is added for convenience only. The thickness in all doubtful cases is decided by gauge No. 1, which determines its *effective* value in relation to all contiguous parts.

The preceding gauges should, as a rule, be used on every cartridge inspected; those following should be occasionally tried on uncompleted work.

*Gauge No.* 6.—This measures the inside diameter of the mouth of the case. It should enter at least about half way freely, but should not be loose.

*Gauge No.* 16.—This measures the diameter and approximate length of the cylindrical portion of the lubricated bullet, with the lubricant melted off, so as not to stick in the gauge. The bullet should enter freely and bear evenly, but should not be loose.

NOTE.—These two gauges should fit each other, as above prescribed, for this work.

This condition renders unnecessary the splitting of thousandths, which would be required in making maximum and minimum gauges for these dimensions.

The combination gauge combines the body dimensions of the maximum cartridge with those of the minimum gun-chamber, so that any cartridge which will enter this gauge will enter any proper gun.

It is intended primarily for use in the field, headquarters, &c.; but as an inspecting tool it is meant for a rapid survey of finished work by a superior inspector, or in case of emergency it can well be used to the exclusion of the other gauges, or as a preliminary measure to their final trial of cartridges which it may reject.

The following instructions govern its use:

I. The effective thickness of the cartridge-head, the body dimensions of the case, projection of the bullet, and size of front of bullet are gauged by drawing the straight-edge across the two offsets, at right angles to each other, around the edge of the counterbore.

In one case the straight-edge should touch the cartridge-head and in the other it should slide over it.

II. The recess at the large end of the gauge measures the effective maximum diameter of the cartridge-head.

III. The recess at the other end measures the minimum diameter of the cartridge-head. It should not receive the cartridge-head.

IV. In case the cartridge-head should project unduly when gauged (as in ¶ I) it must be remembered that it may be due to the cartridge exceeding the maximum dimensions elsewhere than in the head. The

defective point may be determined by turning the cartridge in the gauge till it rubs a bright spot.

V. A pressure of 12 pounds is allowable to force cartridges into the gauge.

VI. The gauge is made short enough to start the cartridge from it by rapping the bullet end on a table, &c.

VII. Generally, this gauge tells if a cartridge is too *large*. Firing alone can tell whether it is too *small* for efficiency.

The weights are those of the standard bullet and charge of powder. The small weights serve to determine variations from these standards on any fair balance.

The charge of powder is regulated by the initial velocity.

The practical operation of viewing and gauging is as follows: The 10 paper packages heretofore referred to are uncovered by an assistant, and passed to the inspector with the lids reversed on the bottoms so as not to conceal the lot number.

He takes each package in turn, scans the marking on the head, scrapes along the heads with a straight-edge to detect projecting primers, and looks for any pendant turnings of metal, likely to occur when heads are trimmed or when large bodies are reduced by shaving, &c. Any defective cartridges are placed in the hospital box.

This done, the packages are emptied by the assistant into loose work-boxes, and the empty packages bundled together to await the result of the inspection. Rubber bands answer well for this.

A work-box about 12″×5″×4″ will hold 200 rifle cartridges, with the hospital box, henceforth their constant companion, on top of them. These work-boxes have the lot numbers chalked on them.

Whenever a gauging machine, such as described in Ordnance Note No. 69, can be had, its use will greatly facilitate the remainder of the work, as it will take the place of gauges 1 and 11, and in great part of separate handling with Nos. 12 and 19.

For the inspection of contract cartridges the efficiency of the machine would be increased by making the dies like the combination gauge inside.

No further hand gauging of finished cartridges would then be necessary except an occasional trial with gauges Nos. 12 and 19.

In order to allow for wear the dies are made about a quarter-thousandth of an inch smaller than the maximum gauge No. 1, which they resemble in every other particular. Consequently the failure of a cartridge to pass this machine is not conclusive, but depends upon its trial in the hand gauge No. 1.

The machine is most conveniently served by emptying one of the work-boxes above described into a flat wooden tray about 18″ by 30″ by 1 inch deep. The cartridges being fed from this tray by an assistant, they are returned to the work-box by the machine, being gauged by the inspector for minimum thickness of head as they are falling into the box.

In this way the inspector can readily gauge every other cartridge, which, considering the nature of the defect, is sufficient.

In all these operations the cartridges should be carefully handled, not poured or thrown from box to box, but preferably allowed to slide, or be transferred by inverting the tray over the work-box and then inverting both together. Careless handling is apt to bruise the bullets, and badly bruised bullets are sufficient cause for rejection, if bruised in manufacture.

Before using the gauging machine it should be tested by the standard

plugs and by passing through each die two steel dummies, one with a head of standard thickness, and one exceeding that thickness by 0".001. The former should go freely, and the latter should trip the latch at every die.

The dies should be kept clean by occasional wiping with benzine and a spiral bristle brush and chamois skin. The counterbore should be scraped clean with a pine splinter, and the bearings kept well oiled.

In case the machine cannot be driven by power, it can be run by hand by embracing the driving wheel with a wooden pulley about 18 inches in diameter, fitted with a handle, and its rim weighted with lead.

It should be run uniformly at not over 45 or 50 turns per minute.

But if the gauging machine cannot be had, gauge No. 1 must be used by hand *on every cartridge which is inspected.* With a straight-edge both ends of the cartridge can be gauged at one handling.

In all hand gauging it is well to have two trays set next to each other on a table. The work-box is emptied into one of them by the assistant, who collects the cartridges in convenient handfuls—about 7 is a good number—with the heads all one way, and passes them to the inspector.

The latter sits facing the light, which, if insufficient, may be improved by fastening to the nearest edge of a tray a small mirror turned toward the tray. A hole is cut in the bottom, at the farthest right-hand corner of the tray, through which the cartridges as they are gauged may be dropped into the work-box beneath. A pasteboard valve or a slide under the hole serves to break their fall.

The next step to the use of gauge No. 1, either by hand or by machine, will be to try the cartridges in gauge No. 19, as before described. A twirl of the cartridge when in position serves to show its concentricity.

The total length of this gauge should be the same as that of the body of gauge No. 1 in front of the counterbore.

This is so that in gauging the head for concentricity the length of the body under the head may also be approximately determined, unless this has already been done in using gauge No. 1 by hand. The gauging machine will not detect this defect.

Gauge No. 19 will not determine this dimension exactly, owing to variations in the thickness of head (of which it takes no account) and to varying projections of the mouth of the shell, due to the different shapes given to the under side of the cartridge head, which allow the head to enter more or less into the shallow counterbore at the mouth of the gauge; but the eye will soon be able to detect unusual projections to the front, which can then be specially tested with gauge No. 1, as before described. So that using this gauge thus as a "finder" for gauge No. 1 saves one handling without loss to the accuracy of the inspection.

NOTE.—The purpose of this gauge is mainly to distinguish and prevent certain radical errors of manufacture, such as the eccentric trimming of cartridge heads which is likely to result from the cartridges being held during this operation on an interior spindle, whereas in gauging as in firing they are held by the outside; or that of disregarding the extension in length following the operation of tapering.

If the manufacture is properly planned the run of the work on these points will be so uniform that the invariable use of this gauge can safely be dispensed with. Sufficient dependence can then be placed on the gauge for small heads attached to the gauging machine, and to the occasional use of gauge No. 19.

The same remarks apply to gauges 11 and 14, the former of which can be entirely dispensed with if the gauging machine is used. During

the hand gauging it is well, instead of returning the cartridges at once to the work-box, to arrange them in rows upon the bottom of the tray as they come out of the gauge. When spread out thus they can be rolled back and forth for general inspection as to workmanship and examined for deep die scratches, faults, folds, and bad dents in the metal, and for waxy, bruised, or defective bullets.

This course is better than that of individual inspection, for as the great number of the cartridges are probably good, the defective ones will be more readily detected by their difference.

The hardness of the bullet alloy is determined by dropping the bullet point foremost through a caliber 0.50 barrel, 32 inches long, ten times upon a smooth iron plate.

If of approximately the standard hardness, the bullet should not be shortened less than 0''.02 nor more than 0''.04.

The strength of the crimp is determined directly by requiring it to support for a few moments a weight of 25 pounds applied to the bullet.

A few bullets should be drawn from time to time and the lubricant examined to see that there is none left on the base of the bullet and that all the grooves are properly filled. To draw the bullet, pinch its point in a vise and pull on the case by slide wrench or the like, bearing against the under side of the head. All wax should be wiped off the outside of the cartridge, as it serves to catch dust in service.

Solid-head cartridges should be occasionally tried by splitting open a fired shell and filing off the head down to the body. Then holding the shell by its mouth in a vise, pry out the pocket so as to sever the little ring which should now bind it to the walls. This should be about 0''.01 thick, should tear rather than break, and should show no sign of fold or fouling. Otherwise it shows a tendency to burst, to which some solid-head cartridges are liable.

NOTE.—This is no part of the inspection, which is satisfied with a proper actual performance of the cartridge in firing. It is valuable for information only.

Bullets are weighed finished, but free of wax, which can be easily scalded off by a jet of steam.

The cartridges having been viewed and the paper packages having been incidentally examined, they can all be returned to the contractor for repacking and boxing.

In the mean while the contents of the ten hospital boxes are carefully revised and compared together, so that the result of the inspection may be rendered more consistent than if each lot were decided on separately.

The number and nature of the defects are entered in tabular form in the inspection journal, and serve as the basis of the report. (See Appendix.)

The hospital boxes should be carefully secured and permanently preserved by the inspector, as they are the very best vouchers to his conduct of the inspection, and offer the plainest evidence as to its actual operation in case modifications of it are proposed.

For the same reasons he should secure his inspecting samples, and should keep a daily journal and copies of correspondence.

Should any lot be unacceptable, the nature of the defects should be communicated to the contractor, so as to give him a chance to object as well as to correct them in future.

This should be done formally as soon as possible by the inspection report, of which an example is appended. One copy also is sent to the Chief of Ordnance and one retained.

Lots which are not acceptable are returned to the contractor for his

re-examination. When presented anew they are again inspected under the former rules; but to give the second inspection the increased severity which it deserves, the allowable proportion of defects is reduced one-half by doubling the number of cartridges in which they are sought, the tolerance remaining the same numerically, although proportionately reduced one-half. This course is adopted instead of simply reducing the allowable number of defects for two reasons: First, the re-inspection covers more ground; second, there are some defects, bursts, misfires, &c., of which only *one* can ever be allowed.

Having found a defect, either in the course of the firing or of the viewing and gauging, it will be within the discretion of the inspector whether to make the re-inspection general in its character or only to repeat that part of it in which the defect was originally found.

As a rule, any defect preventable by the contractor's own inspection when it occurs in excess, serves to taint the entire lot wherever the defect may be found, and so to require its complete re-inspection.

The effect is to increase the watchfulness of his employés, upon whom, if easy precautions have been taken, can be made to fall the consequences of their neglect.

In such cases as misfires, or an undue proportion of leaky or pierced primers or irregular velocities, where no amount of re-examination would serve to eliminate the defective cartridges, it is of course unnecessary to put the cartridges through a complete re-inspection, and the double number required can be immediately fired.

Any exception to the rule and the reasons for it should be stated in the column of remarks of the inspection report.

Inasmuch as when work is presented for inspection the presumption is that it is good work, the cost of the ammunition expended in verifying this presumption should be borne by the purchaser, particularly if no fault be found with the work. So for all firing as from special arms, or for special reasons, for the information of the purchaser.

But once failing to be accepted, the presumption changes, and is, during the re-inspection, that the work is still bad. Hence the burden changes to the contractor, who loses the cartridges fired in proof.

Since many reasons require the absolute abstention of the inspector from perquisites of any kind, he should be careful to have the scrap brass or copper, and the lead when it can be recovered, accounted for by an allowance in settlement of account.

This is particularly important when the inspection is in the nature of an arbitration, as between a contractor and a foreign government, where undue gains from either party are inadmissible.

Supposing the ten lots, or 100,000 cartridges, to have all been accepted and boxed, they should be spread out for sealing by the inspector.

This is most rapidly done by melting the wax in a large ladle or kettle, from which small ladles full are taken as required.

One man pours from these ladles into the sealing countersinks; he is followed by the inspector with his seal, and if the wax is hot and fluid as it should be, the inspector is followed by a third man with a pitcher of cold water, which he pours on the hot wax as the seal is removed. This chills the wax and prevents obliteration by the internal heat.

The seal should be occasionally cooled in the water and cleaned with some alcohol and a stiff brush.

When the cases are spread out they can be examined generally as to their condition, besides making a special examination of the sample case. Broken boxes should be replaced. A good box should stand when packed a three-foot fall on a hard road, striking cornerwise.

Then the certificates of inspection are signed, which completes the inspection. A quadruplicate copy should go with the inspector.

The rate of inspection depends very much on the quality of the work. With every thing in good order, including the work, about five lots of 10,000 each can be inspected per day.

With a gauging machine such as described in Ordnance Notes No. 69, two or three times this work could easily be done if the cartridges were good.

Herewith will be found Plate I, showing arrangement of velocity targets.

Plate II. Form and dimensions of inspecting gauges and of test-plugs.

Plate III. The shape and inspecting points of the cartridge.

Blank contract.

Blank inspection report.

List of useful articles.

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## APPENDIX A.

(In quintuplicate.)

This contract, made and entered into this —— day of ——, one thousand eight hundred and ——, between the —— —— company of ——, in the State of ——, of the first part, and the United States, by Brigadier-General ——, Chief of Ordnance, acting under the direction and by authority of the Secretary of War, for and in behalf of the second part, witnesseth:

That the party of the first part does hereby contract and engage with the United States to furnish —— (——) metallic solid-head rifle-ball cartridges, caliber 0''.45, in accordance with the following specifications as to dimensions, limits, and weights of the cartridges, and as to the manner of their inspection, viz:

1. *Gauging.*—The inspector will be governed by the actual sizes of the standard gauges supplied by the Ordnance Department, whatever discrepances may exist between the nominal measurements of these gauges and their indicated measurements by any other standard.

2. Each cartridge will be gauged separately in such of its parts as may be required by the inspector.

3. *Marking.*—The date and place of manufacture and designation of the cartridges will be stamped upon the head of each cartridge, in the manner to be prescribed by the inspector. The date of manufacture will also be branded or stamped on one side of each packing-box.

4. *Packing.*—The cartridges will be packed in paper boxes of approved patterns. The wooden packing-boxes will be well and securely made according to established standards.

5. *Inspection.*—The inspection, as far as possible, will be confined to the finished work, and for this purpose the cartridges will be presented for inspection in lots of 10,000, loaded and packed in their proper boxes, which will not be closed. Two hundred cartridges will be taken indiscriminately from each lot and gauged by hand, and twenty-five will be fired, five of them for velocity. If such inspection should develop defects of the kind and to the number hereinafter enumerated, the entire lot will be reinspected by an examination of double the number of the cartridges first taken, viz: Four hundred for form, dimensions, and weight, and fifty for firing. Otherwise the lot will be accepted, and the boxes sealed and marked to indicate the number of the lot. The lot may be looked over meanwhile by the —— —— company for the elimination of these defects before reinspection. If the reinspection should develop defects of the kind and to the number hereinafter enumerated, the entire lot of 10,000 cartridges will be rejected.

The occurrence of any of the defects named below, in either inspection, will be sufficient cause for the reinspection or the rejection of the lot, as the case may be, viz:

2 cases of passing limits for workmanship, material, or velocity.

1 case of extractor cutting through.

2 cases of want of cleanliness from imperfect wiping, or of the presence of wax on the base of the bullet.

1 case of imperfect crimping.

2 cases of leaking back outside of shell.

1 case of misfire.

1 case of projecting primer.

1 case of loose primer.
1 case of bursting or splitting in proof.
2 cases of leakage in or around primer.

And such other cases of special defects as may be developed by the inspection. Their kind and permissible number to be determined by the inspector.

6. In the discretion of the inspector, from time to time, ten cartridges will be taken from each lot to be fired and reloaded. In case any two such cartridges should burst in the course of five successive reloadings, the lot will be subject to reinspection for this defect in the manner elsewhere prescribed.

7. All firing shall be done from a Springfield rifle having a cartridge-head space from 0''.07 to 0''.08 in thickness, and a firing pin projecting between 0''.07 and 0''.08 or as required by the inspection of small arms in manufacture.

8. Although the inspection will, as a rule, be confined to the finished cartridge, leaving to the manufacturer the entire choice of methods for his production, yet, where a detailed examination of the components of the cartridge is required before its loading, such inspection will be made.

9. The company will notify the Chief of Ordnance at least one month before their deliveries for inspection will begin, so that a sub inspector may be sent to watch the early stages of the work. His wages, at the rate of $4.50 per day, will be paid by the United States for this time, and for whatever time afterwards he may be actively engaged in the inspection; but whenever the deliveries for inspection shall, in the discretion of the inspector, be insufficient to keep the subinspector actively employed, then the expenses of the subinspector for such time shall be equally divided between the parties hereto, in settlement of account.

All these cartridges are to be packed by the party of the first part, if required, in good and sufficient boxes of an approved pattern, for which no charge is to be made.

All these cartridges are to be delivered by the said party of the first part at the ——— arsenal before ——— ———.

Payments for each delivery, as hereinafter provided, are to be made on certificates of inspection and receipt by the United States inspectors.

And the said party of the first part does further engage and contract that no member of or delegate to Congress *is, or shall be,* admitted to any share or part of this contract or agreement, or to any benefit to arise thereupon; but this stipulation is not to be construed to extend to this contract if the same be entered into by an incorporated company for the general benefit of such incorporation or company.

And it is hereby expressly provided, and this contract is upon the express condition, that if any member of or delegate to Congress, officer of the Army, agent of the military service, or other prohibited person, *is or shall be* admitted, contrary to law or regulations, to any share or part of this contract, or to any benefit to arise under it, the same shall be, as against the United States, absolutely null and void.

It is further stipulated and agreed that neither this contract or any interest therein shall be transferred by the party of the first part to any other person, and that any such transfer shall cause its annulment so far as the United States are concerned, but without affecting their right to recover for any breach of the same by the contracting party of the first part.

It is further stipulated and agreed that, if any default shall be made by the party of the first part in delivering all or any of the cartridges mentioned in this contract, of the quality and at the times and places therein provided, then, in that case, the said party shall forfeit and pay to the United States the sum of ——— thousand dollars as agreed and liquidated damages.

Nothing in this stipulation contained shall be construed to prevent the Chief of Ordnance, at his option, upon the happening of any such default, from declaring this contract to be thereafter null and void, without affecting the right of the United States to recover for defaults which may have occurred; but in case of overwhelming and unforeseen accident by fire or otherwise, the circumstances shall be taken into equitable consideration by the United States before claiming forfeiture for non-delivery at the time specified.

The said party of the first part shall indemnify the United States and all persons acting under them for all liability on account of any patent rights granted by the United States which may affect the cartridges herein contracted for.

And the said United States do hereby contract and engage with the said party of the first part as follows: That for the cartridges herein contracted for which shall be delivered, inspected, and approved as aforesaid, there shall be paid by the United States, in the funds which the Treasury Department may provide to the said company, the covenantor, on bills in triplicate, made in approved form, and duly authenticated by the proper officers of the Ordnance Department, the sum of ——— dollars per thousand.

**Signed, sealed, and delivered in presence of**

——— ———, [SEAL.]
——— ———, [SEAL.]
***Brigadier-General, Chief of Ordnance.***

## APPENDIX B.

(FORM 41*b*.)

## INSPECTION REPORT OF SMALL-ARM AMMUNITION.

LOWELL, MASS., *December* 18, 1879.

Inspection report of lot No. 27, of 10,000 rifle-ball cartridges, cal. 0.45, manufactured for the United States Ordnance Department by the United States Cartridge Company, under contract dated August 16, 1879.

*Inspection record.*

Number of cartridges in lot, 10,000.
Lot presented for inspection December 10, 1879.
Lot inspected December 11–12, 1879.
Lot (returned for re-examination) December 12, 1879.
Lot returned for reinspection December 15, 1879.
Lot (accepted) December 18, 1879.

*Inspection.*

| Lot No. 27. | First inspection. | | | | | | | Reinspection. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Limit. | Number. | | | | | Remarks. | Limit. | Number. | | | | | Remarks. |
| *No. to be- and- viewed and gauged* | 200 | 200 | | | | | | 400 | 400 | | | | | |
| Casualties: | | | | | | | | | | | | | | |
| Passed limits | 2 | 3 | | | | | 1 scratched case. | 2 | | | | | | |
| Bad crimps | 1 | | | | | | 2 long bodies. | 1 | | | | | | |
| Waxy bullets | 2 | | | | | | 3 | 2 | | | | | | |
| Fold in head | ...... | | | | | | | | | | | | | |
| Projecting primers | 1 | 1 | | | | | | 1 | | | | | | |
| Loose primers | 1 | | | | | | | 1 | | | | | | |
| Total | ...... | 4 | | | | | | Total. | .......... | | | | | No defects. |
| | | Standard rifle. | Maximum rifle. | Minimum rifle. | Gatling gun. | Reloaded ... times. | | | Standard rifle. | Maximum rifle. | Minimum rifle. | Gatling gun. | Reloaded ... times. | |
| *No. to be- and- fired* | 25 | 25 | .. | .. | .. | .. | Condition of firing-pin good. | 50 | 50 | .. | .. | .. | .. | Condition of firing-pin good. |
| Casualties: | | | | | | | | | | | | | | |
| Missed fire | 1 | .... | | | | | | 1 | .... | | | | | |
| Pierced or leaky primers | 2 | .... | | | | | | 2 | 1 | | | | | |
| Loose primers | 1 | .... | | | | | | 1 | ... | | | | | |
| Case leaked back | 2 | .... | | | | | | 2 | 1 | | | | | |
| Burst or split | 1 | .... | | | | | | 1 | .... | | | | | |
| Failed to extract | 1 | 2 | .. | .. | .. | .. | Small heads. | 1 | .... | | | | | |
| Initial velocity | 1325 | 1319 | .. | .. | .. | .. | Average of 5 shots. | 1325 | 1320 | .. | .. | .. | .. | Average of 10 shots. |
| Initial velocity, highest | 1350 | 1325 | | | | | | 1350 | 1326 | | | | | |
| Initial velocity, lowest | 1300 | 1316 | | | | | | 1300 | 1318 | | | | | |
| M. A. D., @ 500 yards | 0.92 | 1.16 | .. | .. | .. | .. | 10 shots; φ = elevation for 475 yds; fixed rest. | | | | | | | — shots; φ =. |

### REMARKS.

The occurrence of the long bodies and small heads, preventable by a careful preliminary inspection, compel me to return this lot for re-examination. A. B., Dec. 12.
* Lot accepted on reinspection. A. B., Dec. 18.

*NOTE.—Reinspection report made out separately on right-hand side for Chief of Ordnance. For inspector and contractor, first inspection report recalled and completed.

I certify that the above inspection-report is in all respects correct, and that the paper and wooden boxes in which the cartridges are packed are equal to samples furnished.

A. B.,
*Sub-Inspector.*

Approved, and respectfully forwarded to the Chief of Ordnance, December 20, 1879.

C. D.,
*Lieut. of Ordnance, Inspector.*

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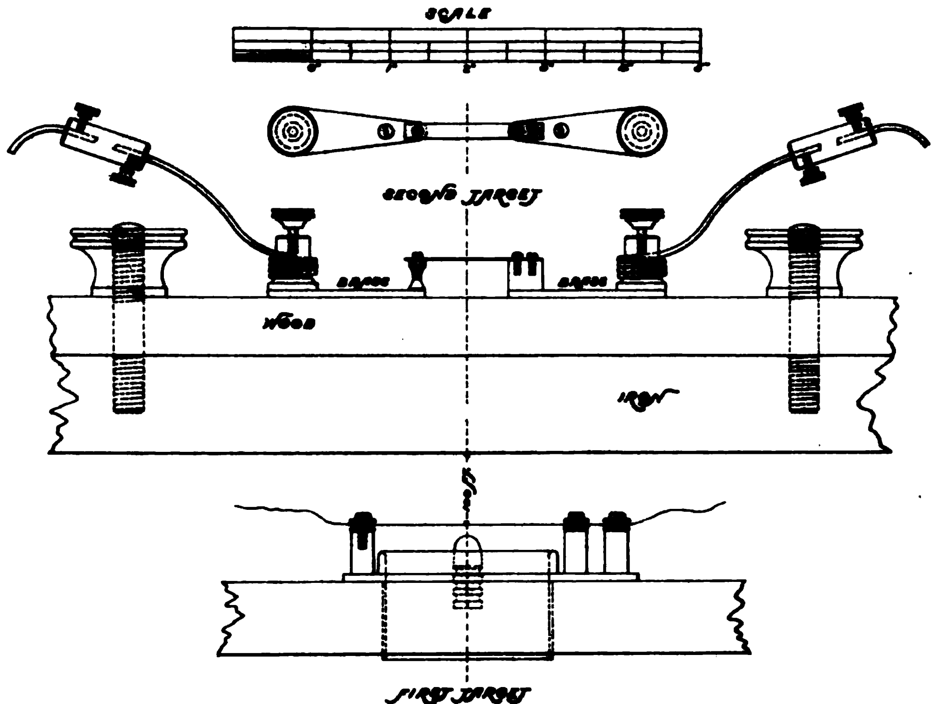
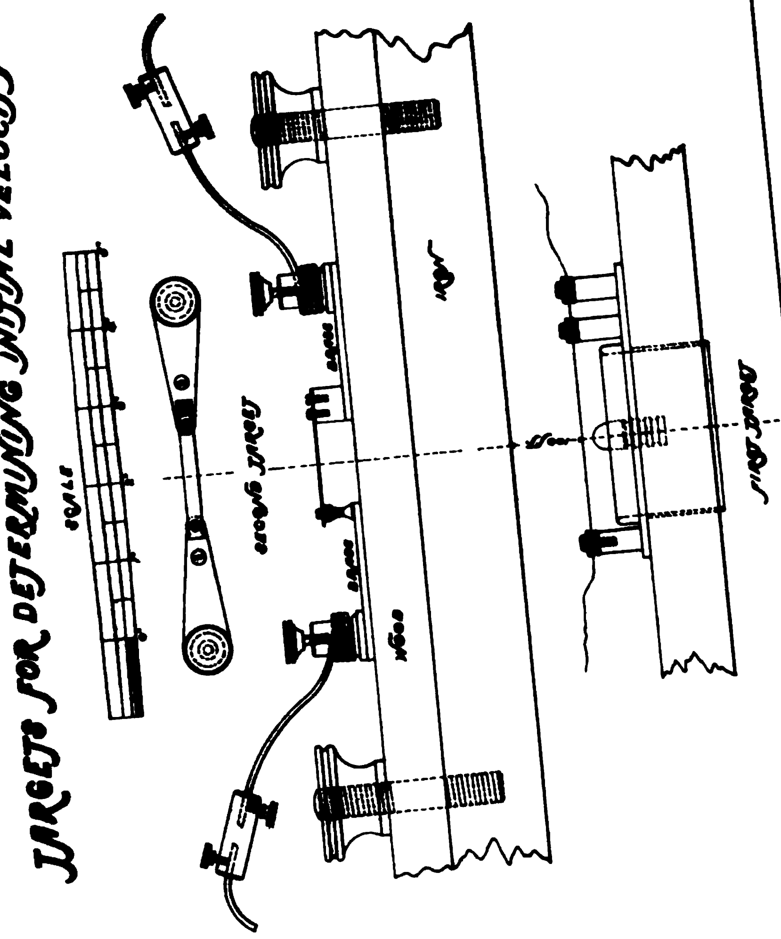
## APPENDIX C.

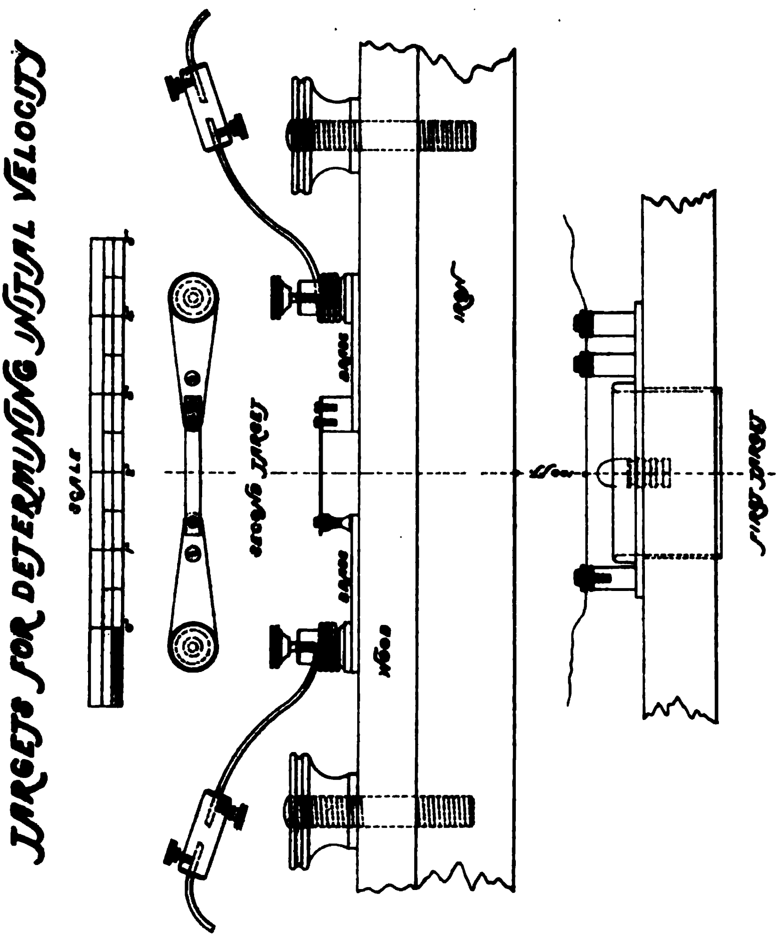
*List of useful articles.*

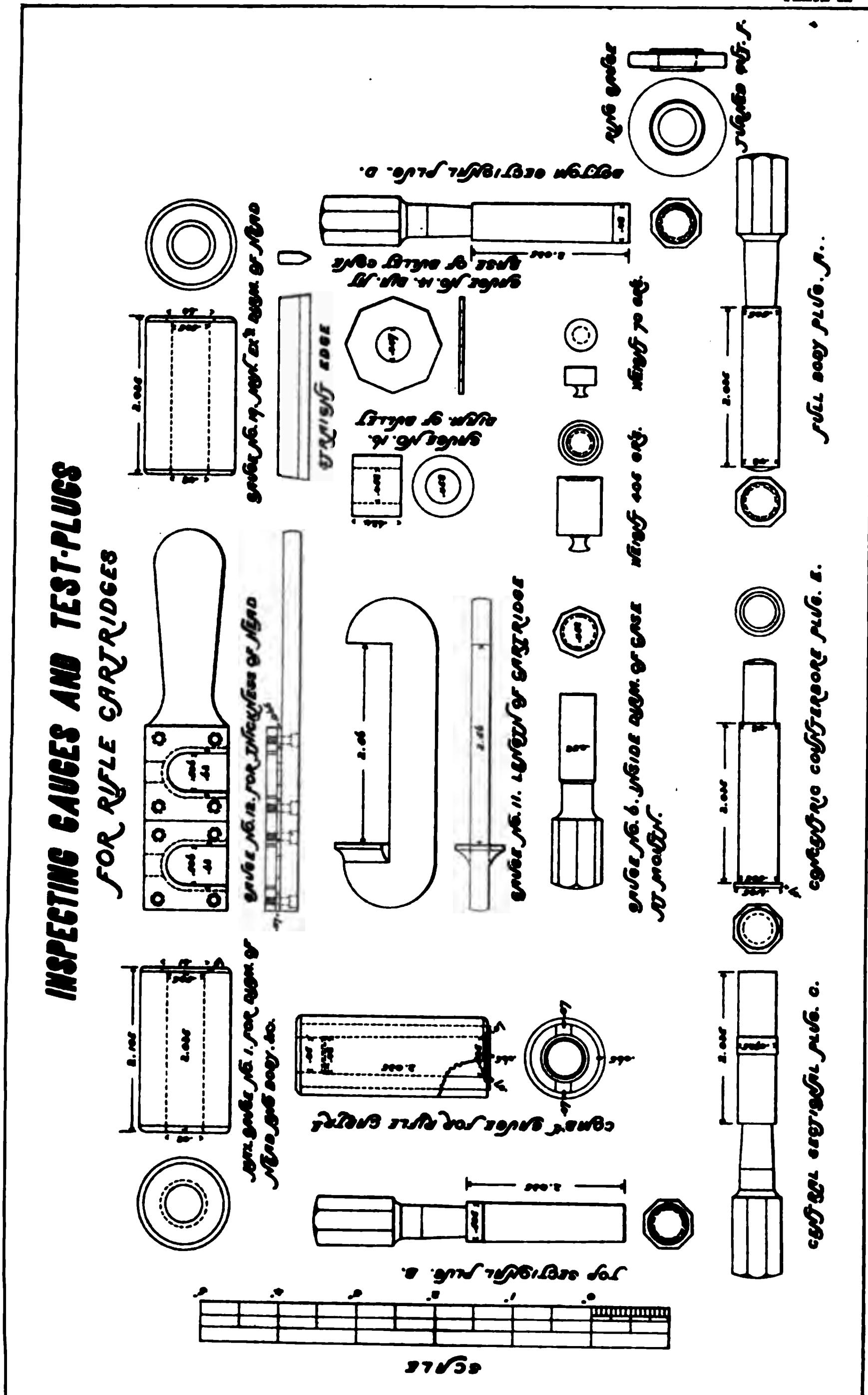
1 gatling gun, 5 barrel, short, with tripod and implements complete (or other machine gun), 10 feed cases.
2 standard Springfield rifles, with counterbore space about 0''.075, mouth of chamber about 0''.506, projection of firing-pin between 0''.07 and 0''.08 (1 rifle as a reserve).
1 maximum Springfield rifle, with counterbore space about 0''.085, mouth of chamber about 0''.510, projection of firing-pin between 0''.07 and 0''.05.
1 minimum Springfield rifle, with above dimensions as close to minimum gauge as possible, except firing-pin, which should project to maximum distance.
1 Hotchkiss magazine rifle, or other magazine rifle.
12 spare firing-pins.
2 spare rifle stocks. (They are apt to break in firing for velocity from a fixed rest.)
1 Le Boulongé chronograph complete with batteries (Bunsen) targets, per report.
500 feet No. 16 copper wire.
2 lbs. braided office wire, about No. 20.
2 lbs. No. 30 or 32 copper wire.
2 doz. connecting cups.
1 lb. double-pointed tacks.
1 telephone complete.
1 cartridge gauging machine, with combination dies.
1 set of gauges, per report, and test plugs.
1 set of flange gauges (dummies) for testing gauging machine.
1 set of same for testing Gatling gun counterbore space.
1 33-inch tube for testing bullets.
1 set button gauges for measuring counterbores.
1 vernier scale.
1 balance, to weigh 2 or 3 oz., sensitive to 0''.1 gr.
1 galvanometer. Fire-alarm will do.
1 set of standard reloading tools.
1 chest or closet with special Yale lock.
1 inspecting seal.
10 work-boxes.
2 work-trays.
1 inspection journal.
Blank report, certificates of inspection, brushes, chamois skins, alcohol, &c

# TARGETS FOR DETERMINING INITIAL VELOCITY

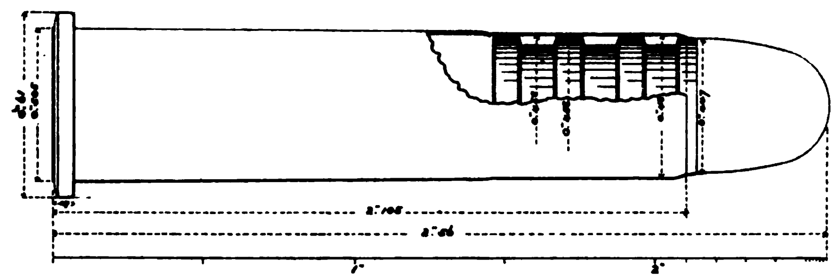



TARGETS FOR DETERMINING INITIAL VELOCITY
SCALE
SECOND TARGET
BRASS
BRASS
WOOD
IRON
FIRST TARGET


TARGETS FOR DETERMINING INITIAL VELOCITY
SCALE
SECOND TARGET
FIRST TARGET


INSPECTING GAUGES AND TEST-PLUGS
FOR RIFLE CARTRIDGES

# MAXIMUM DIMENSIONS OF STANDARD RIFLE CARTRIDGE




FOR DETAILS SEE ORDNANCE NOTE LXXIX REVISED EDITION

# APPENDIX 20.

## CAPTAIN DUTTON'S REPORT ON THE GEOLOGY OF THE HIGH PLATEAUS OF UTAH.

The Chief of Ordnance desires to bring to the notice of the officers of the Ordnance Department the verdict of scientific opinion upon the recent work of Capt. C. E. Dutton, of the Ordnance Department, entitled The Geology of the High Plateaus of Utah. For this purpose he causes to be printed herewith two reviews, selected from the principal scientific journals of America and England. The first is from the American Journal of Science, July, 1880, and is written by Prof. James D. Dana, of New Haven. The second is from the English journal Nature, of August 5, 1880, and is written by Prof. Archibald Geikie, R. R. S., director of the Geological Survey of Scotland.

S. V. BENÉT,
*Brigadier-General, Chief of Ordnance.*

(From the American Journal of Science, July, 1880.)

### THE HIGH PLATEAUS OF UTAH.*

The region which is the subject of this report is one of unexcelled grandeur in the extent of its mountain plateaus, in its simple system of geological structure and displacements, and in the magnitude and diversity of the effects of erosion, and Captain Dutton, in his account of it, shows that he is capable of appreciating and discussing the geological problems which it presents.

The High Plateaus, as the report states, occupy a large part of the southern half of Utah, commencing on the north at a point in the Wahsatch range about 15 miles east of Mount Nebo, and having a length of about 175 miles, with a breadth of 25 to 80 miles. The region is divided by two profound, nearly north and south valleys; a western, along the Sevier River, which here flows north to the westward bend that takes it to Sevier Lake, "a wretched salina of the Great Basin;" and an eastern, called Grass Valley, along two tributaries of the Sevier, a northern and southern, which combine to make the "East Fork of this river." On the west of the Sevier Valley three plateaus are distinguished, namely, commencing to the north: The Pavant, "a curious admixture of plateau and sierra;" the Tushar, "its northern half a wild, bristling cordillera, its southern conspicuously tabular;" and the Markágunt, "a true plateau," about 11,000 feet in height. Between the Sevier and Grass valleys there are two plateaus—the Sevier, 80 miles long, cut through near its middle by the east and west gorge of the East Fork; and south of this the Paunságunt Plateau, "bounded on three sides by lofty battlements of marvelous sculpture and glowing color." East of Grass Valley, and its line to the south (along which commences the Paria River), three pla-

*Report on the Geology of the High Plateaus of Utah*, with Atlas; by C. E. Dutton, Captain of Ordnance, U. S. A., U. S. Geographical and Geological Survey of the Rocky Mountain Region, J. W. Powell in charge: Department of the Interior. 307 pp., 4to, with 11 heliotype plates and a folio atlas. Washington, 1880.

teaus are distinguished: the Wahsatch, extending somewhat farther north than the Pavant (to the parallel of 40°), where it joins, in an *en échelon* way, the Wahsatch range proper; the Fish Lake Plateau, east of Fish Lake, but 15 miles long, yet 11,400 feet high; the Awapa Plateau, which almost blends with the preceding but is of less altitude, and is 30 miles long by 20 in breadth, its top a treeless rolling prairie, sloping feebly to the eastward; and the Aquarius, 11,600 feet high in its eastern part, 35 miles in length by 10 to 18 in breadth, the grandest of all the High Plateaus, its "three sides—the south, west, and east—walled by dark battlements of volcanic rock," and descending to "the dismal desert in the heart of the plateau country," while its broad summit is clad with forests of spruce, and has its grassy parks and scores of snow-fed lakes.

The wonderful contrast between the desert country below to the south and southeast, "dismal and suggestive of the terrible," and the forest covered summit of the Aquarius Plateau, has much meteorological interest as regards the whole mountain region, and we cite a paragraph from page 285 of the report:

> The ascent leads us among rugged hills, almost mountainous in size, strewn with black bowlders, along precipitous ledges, and by the sides of cañons. Long detours must be made to escape the chasms and to avoid the taluses of fallen blocks; deep ravines must be crossed, projecting crags doubled, and lofty battlements scaled before the summit is reached. When the broad platform is gained the story of "Jack and the Beanstalk," the finding of a strange and beautiful country somewhere up in the region of the clouds, no longer seems incongruous. Yesterday we were toiling over a burning soil, where nothing grows save the ashy-colored sage, the prickly pear, and a few cedars that writhe and contort their stunted limbs under a scorching sun. To-day we are among forests of rare beauty and luxuriance; the air is moist and cool, the grasses are green and rank, and hosts of flowers deck the turf like the hues of a Persian carpet. The forest opens in wide parks and winding avenues, which the fancy can easily people with fays and woodland nymphs. On either side the sylvan walls look impenetrable, and for the most part so thickly is the ground strewn with fallen trees that any attempt to enter is as serious a matter as forcing an *abattis*. The tall spruces (*Abies subalpina*) stand so close together that even if the dead wood were not there a passage would be almost impossible. Their slender trunks, as straight as lances, reach upward a hundred feet, ending in barbed points, and the contours of the foliage are as symmetrical and uniform as if every tree had been clipped for a lordly garden. They are too prim and monotonous for a high type of beauty; but not so the Engelmann spruces and great mountain firs (*A. engelmanni*, *A. grandis*), which are delightfully varied, graceful in form, and rich in foliage. Rarely are these species found in such luxuriance and so variable in habit. In places where they are much exposed to the keen blasts of this altitude they do not grow into tall majestic spires, but cower into the form of large bushes, with their branchlets thatched tightly together like a great hay-rick.

This meteorological contrast, as the author remarks, is explained by the fact that the summit receives not far from 30 inches of rain a year, because so high among the clouds, while the low country around has but 4 to 8 inches.

The southern boundary of these high plateaus is near the southern boundary of Utah, the parallel of 37°. Beyond, lies the plateau country described by Powell, the region of the Shiwits, Uinkaret, Kanab, Kabiab, and Paria plateaus, on the north side of the "Grand Cañon" of the Colorado, which here extends nearly east and west between the parallels of 36° and 36° 30′, and of "Marble Cañon," "Kanab Cañon," "Hurricane Cliffs," "Echo Cliffs," and other remarkable features.*

The Henry Mountains, described by G. K. Gilbert, stand 30 miles to the east of the Aquarius Plateau.

In the geological account of these plateaus the author treats of the geological formations, the positions and disturbances of the strata, and

* See Powell's Report on the Uintah Mountains; also this Journal, III, xii, 420, and Dana's Manual of Geology, edition of 1880, page 792.

the bearing of the facts on questions connected with mountain-making, the distribution and character of the igneous rocks, the nature and origin of volcanic action, and the results, methods, and periods of erosion.

The distribution of the formations is exhibited on a large colored chart. They include the *Carboniferous*, making the summit and western side of the Pavant or northwestern plateaus; the *Triassic*, in Western Utah, at the eastern base of the Awapa and Aquarius plateaus, and with it the *Jurassic*, and the latter also outcropping in narrow strips in the Sevier River Valley; the *Cretaceous* (with which the Laramie or Lignitic group is united by Captain Dutton), bordering the plateaus, and rising, in several of them, nearly to the summit; the *Eocene tertiary*, constituting part of the slopes on the north, south, and east of the plateaus, and making the summit formation of the Wahsatch Plateau on the north of small portions of the Fish Lake and Tushar plateaus, and of a large part of the Markágunt Plateau in the southwest. Going from the southern plateaus southward to the Colorado, a wide area of Eocene tertiary is first passed; then bands, in succession, of Cretaceous, Jurassic, Upper Trias, Lower Trias (Shinarump group), and Carboniferous.

The youngest group in the series clearly made out (the Quaternary excluded) is thus the Eocene; and it would be the summit formation generally were it not for the erosion that has taken place, and still more for the covering of igneous rocks. These Eocene beds are part of an extended lacustrine formation—as first recognized by Marsh. They are described as 5,000 feet thick around the flanks of the Uintas and southern Wahsatch, and as thinning outward from these mountains to nearly or quite 2,000 feet.

The volcanic rocks are spread over the summits of the Aquarius, Awapa, and Fish Lake plateaus on the east, the great central Sevier Plateau and the Tushar and Markágunt plateaus on the west; and they have a thickness in some parts of 4,000 or more feet. The rocks are chiefly trachytes, with some andesite, propylite, and dolerite; and the trachytes are described as intermediate in age between the andesite and propylite, which are the oldest, and the dolerites, but as in alternating beds in some places with the last. In the Awapa and Aquarius plateaus the trachyte shows a thickness in some of the profound gorges of 3,000 feet. The volcanic eruptions are stated to have begun in the Middle Eocene, and a few of the foci are still distinguishable. The basaltic eruptions in some places look, "so far as appearance is concerned," as if they "might have been erupted less than a century ago." Besides the eruptive beds, volcanic conglomerates are widely distributed, they covering an area of 2,000 square miles, and being in some parts 2,500 feet thick. In some places they have been so changed as to lose their fragmental character, and become in appearance closely like true eruptive rocks (a fact which has been observed also in the Andes and Mexico). But they fail, says Captain Dutton, of the fluidal character and glass inclusions of the latter. For the author's discussions with regard to the volcanic rock and volcanic action and its causes, the reader is referred to the report.

The disturbances in the plateau region have resulted in a general uplifting, and also in monoclinal flexures, and in fractures and faults; and the faults are mostly in the line of monoclinal uplifts, as brought out by Powell in his description of the Colorado region on the south. The flexures and faults, as is well illustrated in the atlas, have approximately a north-and-south course, and are, in part, a continuation of those of the Colorado region on the south. The "Hurricane fault" has its southern

limit at some undetermined point in Arizona, south of the Colorado, and at its crossing of the Grand Cañon it is the line of a displacement of 1,800 feet. It is the western boundary of the Markágunt uplift (the southwestern), making at one place a displacement of 5,000 feet, and at the southwest base of the Markágunt elevation bringing up the Carboniferous to a level with the Tertiary, a displacement of 12,000 to 13,000 feet. It reaches north to the west side of the Tushar Plateau and by the east side of the Pavant. Other faults have less extent, but there is great similarity among them in character and direction. The amount of throw is in general from a few hundred to 3,000 feet. The time when these displacements took place is not indicated by the displaced beds, for no beds occur later than Eocene. Captain Dutton refers the principal displacement to the Middle Pliocene, and suggests, on the ground of facts connected with the erosion of the region, that some have been formed even as late as subsequent to the Glacial period. These displacements are wholly distinct from those which occurred at the mountain-making epoch after the Laramie period, upturning the Cretaceous and inferior beds, being a result of subsequent movements. After that epoch a large part of the Rocky Mountains was raised from near the ocean's level; and the production of the monoclinal flexures, long lines of faults, great volcanic eruptions, and profound denudation must have been dependent more or less on this grand movement or the causes producing it.

Captain Dutton points out the contrast between the simple monoclinal flexures and nearly horizontal bedding of the plateau mountain region, and the high dips and numerous folds of the Appalachians. The contrast is not so striking when the comparison is made with the Cumberland table land and its continuation southwestward into Tennessee and northward into Southern New York and the Catskills, which are parts of the results of the Appalachian revolution; and may it not be that the High Plateaus are in a similar way the denuded outskirts of the Wahsatch, which afterward became somewhat crumpled and displaced while the uplift of the Rocky Mountain region was in progress?

The subject of erosion is treated ably and with full appreciation of the grandeur and geological interest of the results in this plateau region; and several heliotypes represent some of the wonderful scenes in the mountains. The author estimates that on an average at least 6,000 feet of rock in depth have been removed from the plateau province since the erosion began—that is, during the Miocene and subsequent time—from an area of 10,000 square miles. The erosion was least in the High Plateaus, the average being less than 1,000 feet, chiefly because of the protection they received from the covering of volcanic rocks. He says (pp. 21, 22):

The great erosion of the plateau province was most probably accomplished mainly in Miocene time, but continued with diminishing rapidity throughout the Pliocene. But it is necessary to say that the terms Miocene and Pliocene have here no definition. They cannot be correlated except in a very general manner with events occurring outside the province. We have only a vast stretch of time, with an initial epoch near the close of the local Eocene. The greater part of the denudation is assigned to the Miocene, because the conditions appear to have been more favorable to a rapid rate of destruction in that age than subsequently. The climate appears to have been humid, while the elevation was at the same time gradually increasing, both conditions being favorable to a rapid disintegration and removal of the rocks. The Pliocene witnessed the gradual development of an arid climate similar to that now prevailing there. To this age belong the cañons and the great cliffs, which could not have been produced in an ordinary or humid climate, nor at low altitudes. That this aridity is by no means a condition of recent establishment is indicated by many evidences. They consist of remnants of a former topography, preserved in a few localities from the general wreck of the

land, and which show the same general facies of cliffs and cañons as those of more recent formation. And as the more recent sculpture owes its peculiarities in great part to the aridity, so we conclude must these more ancient remnants. The Kaiparowits Plateau presents an excellent example. Its surface is in many places rendered utterly impassable by a plexus of sharp narrow cañons, of which the heads have been cut off by the recession of the gigantic cliff which forms the eastern wall of the plateau. They have long been dug, and have remained with but little change for an immense period of time.

And now the relation of the High Plateaus to the plateau province at large becomes evident. They are the remnants of great masses of Tertiary and Cretaceous strata left by the immense denudation of the plateau province to the south and east. From the central part of the province the Tertiary beds have been wholly removed and nearly all the Upper Cretaceous. A few remnants of the Lower Cretaceous stretch far out into the desert, and one long narrow causeway, the Kaiparowits Plateau, extends from the southeastern angle of the district of the High Plateaus far into the Central province and almost joins the great Cretaceous mesas of Northeastern Arizona, being severed from them by the Glen Cañon of the Colorado. The Jurassic has also been enormously eroded. This formation, which is of great importance and bulk in the northern and northwestern portion of the province, and especially around the High Plateaus, appears to have thinned out toward the south and southeast. In large portions of New Mexico it is wholly wanting and was probably never deposited there. In the northwestern portion of that Territory only a few thin beds of that age are found. But in the northern part of the province a conspicuous and wonderful sandstone formation of most persistent character is found, overlaid and underlaid by shales holding a distinctly Jurassic fauna. This formation once extended over the Grand Cañon area, probably as far south as the river itself, and possibly farther, but has all been swept away as far north as the southern end of the district of High Plateaus. From the region east of the High Plateaus also very large areas of it have been removed. The Upper Trias has also been greatly denuded, and the Lower Trias nearly as much so. The erosion of the Carboniferous has been small, being confined chiefly to the cutting of cañons—most notably the Grand and Marble cañons, which are sunk wholly in that series; and in several places have been cut through the entire Palæozoic series system.

In the discussions with regard to the nature of volcanic action and the origin of mountain disturbances, Captain Dutton rejects the idea of the earth's interior liquidity, and holds that the theory of the earth's contraction, as a cause of movement, is inadequate to account for the facts. At the same time he acknowledges that, in his view, the source of the heat of volcanic action, and that of the force producing the greater changes of level in the earth's surface, are yet without satisfactory explanation. In connection with his remarks on the erosion in the plateau region, he queries whether the removal of 6,000 to 10,000 feet of rock material over so large an area would not "have disturbed the earth's equilibrium of figure, and the earth, behaving as a quasi-plastic body, have reasserted its equilibrium of figure by making good a great part of the loss by drawing upon its whole mass beneath?" He further says that, to account for the uplifts as well, we must almost necessarily refer to the operations of "that mysterious plutonic force which seems to have been always at work and the operations of which constitute the darkest and most momentous problem of dynamical geology"; and also "recognize the co-operation of that tendency, which indubitably exists within the earth, to maintain the statical equilibrium of its levels." But to appreciate rightly the relations of the uplifts to the erosion, and their relative influence on this equilibrium, we have to remember that during the very period of erosion, when 6,000 feet in average depth was being removed (that is, after Eocene time), the mountain region was undergoing an elevation of full twice 6,000 feet.

But the reader should refer to the volume for the author's full discussions on these and the other topics, here briefly reported. The report is made in all parts very readable by the author's graphic descriptions of the region and of the events in its geological history.

J. D. D.

[From "Nature," August 5, 1880.]

## THE HIGH PLATEAUS OF UTAH.*

Until a few years ago the geography of the high grounds of the western part of North America was depicted, even on the best maps, in a manner which now appears almost like a caricature of nature. So much has been said and written about the Rocky Mountains that the popular imagination was wont to picture them as a colossal, rugged, and almost impassable range, extending continuously down the backbone of the continent, and serving generally as the watershed beween the Atlantic and Pacific oceans. The progress of research, however, dissipated this delusion by showing that instead of one continuous chain of mountains, a vast area of country, extending from the British Possessions far down into the Southern States, has been upraised into elevated plains of tablelands, and that these at various distances have been ridged up by lenticular mountain-chains, sometimes parallel, sometimes *en échelon*, and tending generally in a meridional direction. The term "Rocky Mountains" is now commonly restricted to the most easterly line of mountains which, serves as a divide or water-parting between the Atlantic slope and the regions lying to the west. But though the traditional glories of the Rocky Mountains have thus been dimmed, and though the most enthusiastic traveler through their still little known solitudes must in fairness admit that they cannot boast among their innumerable ranges, hitherto visited and described, one which for variety and majesty of outline can be named with the Bernese Oberland, yet this merely nominal degradation is more than compensated by the discovery that these western territories contain a type of high ground to which there is probably no adequate parallel elsewhere on the face of the globe—a type so strange and overwhelming in its first aspect, so weird and almost incredible in its history, that the ordinary language of scenic description fails to convey the impression which the overawed beholder wishes to produce, and he finds himself obliged to borrow a new vocabulary, yet even with its aid is conscious that his narrative, exaggerated as it may seem, falls infinitely short of doing justice to the marvels he has seen.

To the portion of this region which, bounded by the Colorado Park Mountains on the east and by the ranges which border the Great Basin on the west, stretches from Southern Wyoming far into New Mexico and Arizona, the name of the plateau country has been given. It is drained mainly by the Colorado River and its tributaries. Its surface at lower levels than 7,000 feet above the sea is a blazing desert, bright with strange mineral colors, glaring red, livid purple, verdigris green, toned white, and ashy gray. On these plains hardly any vegetation grows. Not a solitary tree, save here and there a gnarled cedar, affords a scanty shade, and little but stunted sage-brush or prickly cactus in scattered tufts varies the eternal monotony of the burning soil. It is a region of perpetual drought, for the springs are believed not to average one in a thousand square miles. Yet the land is traversed by a network of rivers, which, however, wind along in profound chasms, to be crossed only by the birds of the air. So deep and somber are many of these gorges (that of the Colorado being in some places more than a mile deep) that the very sound of their running waters never reaches the level of the plateau above. Only a dim daylight reaches the bottom, and the stars are said

* "Report on the Geology of the High Plateaus of Utah," with Atlas; by Capt. C. E. Dutton, U. S. A., Geographical and Geological Survey of the Territories, J. W. Powell in charge. (Washington, 1880.)

to be visible in certain narrow gorges at midday. But where the level of the plateau rises high enough to condense some of the moisture which the air-currents carry across it, the verdureless aspect of the lower plains is replaced by luxuriant forests and open glades carpeted with rich grass and wild flowers. So colossal, however, are the table-lands that some of them slope gradually out of the range of tree-growth to a height of from 11,000 to 12,000 feet above the sea, and almost lie within the limit of perpetual snow.

So far as yet known, the plateau country reaches the fullest development of its extraordinary features in the southern portions of the Territory of Utah. This region was partially explored by Professor Powell during his surveys from 1869 to 1874, and by the parties under Captain Wheeler, especially by Mr. Howell and Mr. Gilbert, whose published reports form a valuable portion of the third volume of the "Geographical and Geological Explorations west of the one hundreth meridian," conducted by Captain Wheeler. In 1875 Mr. Powell secured the services of Captain Dutton for the investigation of a large volcanic tract among the Utah plateaus, as part of the survey under his direction. Captain Dutton spent the seasons of 1875, 1876, and 1877 at the task assigned him. We have now the result of this labor in the handsome quarto volume and beautiful atlas which has just appeared. This publication is undoubtedly one of the very best of the many admirable contributions to geology which have recently been made by the official surveys of the United States. With the aid of the letter-press, maps, and sections, any geological reader can follow and realize to himself the almost incredible magnificence, as well as simplicity, of the structures of these high plateaus.

The geology of the area may be briefly described as presenting a succession of nearly horizontal sedimentary formations, from the Upper Carboniferous up to the Eocene lacustrine deposits of the West, thrown into a succession of broad folds, cut into segments by a series of important faults, and overlaid toward the north by vast sheets of volcanic ejections, the whole of the rocks aqueous and igneous, having been carved into valleys, gorges, escarpments, outliers, and isolated plateaus of the most imposing magnitude.

From the Carboniferous up to the top of the Cretaceous series there does not appear to be any general physical break in the continuity of the stratification. The Carboniferous rocks are only partially exposed, but the overlying beds—the singular deep purple, chocolate, slate, and brownish-red Shinarump group—attain a greater development, exhibiting their peculiar regularity of sedimentation and their sculptured terraces and outliers. These characteristic strata have been classed as Permian or Lower Triassic, but the researches of last year have, we believe, brought to light fossils which point unmistakably to their Permian age. An occasional want of conformability is observed between them and the overlying Trias, but as a rule the latter follow without discordance and rise into the succession of bright-red and orange sandstones and shales which constitute the great cliff-forming series throughout the plateau country. A geologist accustomed to the scenery of the "New Red" plains of Central England may find it hard to believe that the Trias of Western America forms ranges of vermilion-colored cliffs 1,000 or 1,500 feet high, projecting in vast promontories, retiring into deep bays, and stretching with the same brightness of color and the same regularity of front for hundreds of miles. No very satisfactory line has yet been drawn between the Trias and the Jura. The latter series consists, in the plateau country, of two members, the lower being

a massive gray or white sandstone of great thickness, the upper a series of calcareous and gypsiferous shales, from 200 to 400 feet thick. This sandstone, according to Captain Dutton, was laid down over an area which cannot fall much short of 35,000 square miles, with an average thickness of more than 1,000 feet. Yet so persistent were the conditions of its deposit that from bottom to top, sometimes through a depth of nearly 2,000 feet, it everywhere consists of intricately false-bedded sandstone, without layers or partings of shaly or other heterogeneous matter. From the Upper Jurassic calcareous beds distinctive fossils have been obtained.

The Cretaceous system presents here the usual massive development of sandstones and shales which form so prominent a feature in the geology of the West. The Lower Cretaceous Dakota group is recognized by its lithological resemblance to the corresponding beds in Colorado and elsewhere, and by the occurrence of species of *Ostrea*, *Gryphæa*, *Exogyra*, *Plicatula*, &c. The overlying shales are identified with the Laramie group, which the author places as Upper Cretaceous. The whole of the Cretaceous series is more or less lignitiferous, a considerable number of workable coal-seams in it being already known. At the close of the deposition of the Laramie group the first important break in the succession of the rocks occurs. Extensive disturbance took place along the old Mesozoic shore-line which now bounds the Great Basin on the east, and this was accompanied and followed by such enormous denudation that the Cretaceous series, several thousand feet in thickness, was entirely removed and the oldest Tertiary strata accumulated on the exposed surface of Jurassic beds. Yet so local were these movements that in adjacent tracts the whole Cretaceous series of the region is present, and appears to be followed without interruption by a conformable suite of Eocene strata.

The geographical changes that closed the Cretaceous period in the West were among the most important in the evolution of the American continent. Over many thousand square miles the floor of the sea was raised into land which has never since been again submerged. The lacustrine conditions which began in Cretaceous times now received a far greater development. The waters of the ocean, inclosed into inland seas, from brackish became fresh, and one or more lakes, of perhaps even greater dimensions than those of Eastern America, stretched between the heights of the Great Basin and the Rocky Mountains for as yet an unknown distance to the south. The history of these lakes has been studied by Hayden, King, Powell, and other geologists, and their marvelously rich ichthyic, reptilian, and mammalian fauna has been described by Leidy, Marsh, and Cope. Much remains to be done before the history can be regarded as even approximately filled in. In the meanwhile it is certain that this lacustrine area was undergoing slow subsidence during Eocene time, that sediment was being continually washed into it from adjoining mountains, that eventually 5,000 feet or more of strata were laid down over its site, and that the area of fresh water progressively diminished.

A new chapter in this eventful history is revealed by Captain Dutton. He tells how in Southern Utah the lake, even as far back as the time of the Middle Eocene, was the theater of volcanic discharges, and how these, after vast intervals of quiescence and almost incredible denudation, have been from time to time renewed down even to a period so recent that it can hardly be believed to date so far back as the days of Cortez and the Spanish conquest. He shows that this volcanic district discloses a remarkable variety of phenomena, nearly every form of eruption being

exhibited and every great group of volcanic rocks being represented in it. The earliest volcanic rocks are tuffs, which he regards as probably derived in chief measure from the degradation of older lavas and the deposit of the resulting sediment on the floor of the lake. The next phase of volcanic activity was marked by the outpouring of masses of propylite and hornblende andesite, and was succeeded by the third and grandest of all, when floods of trachytes and rhyolites, alternating with augitic andesites and dolerites, rolled far and wide over the plateaus. The author is doubtful whether these extravasations proceeded from Ætna-like summits or craters, and is rather inclined to look upon the larger deluges as having issued from local fissures. Certainly if any true lofty volcanic cones existed, all external trace of them has been completely effaced by denudation. The closing event in this long volcanic period, if indeed the record can be properly regarded as even yet closed, consisted in the emission of abundant streams of lava round the larger areas of previous activity. Captain Dutton notices some remarkable examples of a feature which occurs on a much smaller scale in the volcanic region of the Rhine and Moselle. The basalt cones and craters whence the streams have emanated seldom appear at the base of the great cliffs or at the bottoms of the deep cañons. They are often crowded together near the crests of the terrace walls, or the lava has broken out from the face of a wall. They commonly lie near lines of fault, yet appear almost always on the uplifted instead of the depressed side of the dislocation. "The least common place for a basaltic crater is at the base of a cliff." Among the volcanic masses special attention is given to the enormous accumulations of conglomerate and tuff, which cover nearly 2,000 square miles of area and range from a few hundred to nearly 2,500 feet in thickness. These vast piles of coarse detritus the author attributes to the atmospheric disintegration of previously erupted lavas, and he describes in detail the process by which similar conglomerates are at the present moment being formed by frost, rain, and mountain torrents. The highly important observation was made by him among the older tuffs that in some places they have been so metamorphosed that the product of alteration is a rock possessing all the ordinary characters of a lava.

The chronological sequence of volcanic rocks among the plateaus of Utah has been recognized as obeying generally the order annunciated by Richthofen. Captain Dutton, starting from this observed sequence, devotes two long chapters to theoretical discussion—one on the classification, the other on the origin, of volcanic rocks. To his work in the field he has added careful labor indoors, especially studying the microscopical and chemical characters of volcanic rocks. No one can read his pages without recognizing their suggestiveness, even though the conclusions reached in them may sometimes appear doubtfully valid. His remarks upon the texture of volcanic rocks (pp. 91–99) offer an excellent sample of his critical treatment. Pointing out how different may be the texture assumed by the same original magma according to whether the mass has cooled and consolidated at the surface or beneath it, he is disposed to regard the intrusive condition as a kind of intermediate stage between volcanic rocks which have issued above ground and non-eruptive masses which have remained inactive deep beneath it, and he regards the porphyritic texture as especially characteristic of his "qualified eruption." This generalization is only partially supported by the volcanic history of Britain. Among our older palæozoic rocks, indeed, the intrusive or injected masses very generally possess the porphyritic structure. But from the time of the lower old red sandstone

onward to the Miocene volcanic period, inclusive, the intrusive sheets are for the most part non-porphyritic, while the porphyritic structure is found among the superficial lavas. The classification our author proposes is as follows:

ACID SERIES—Group I. RHYOLITES.

Sub-group 1. Nevadite, or granitoid rhyolite.
2. Liparite, or porphyritic rhyolite.
3. Rhyolite proper, or hyaline rhyolite.

SUB-ACID SERIES—Group II. TRACHYTES.

Sub-group A. Sanidine trachytes.
1. Granitoid trachyte.
2. Porphyritic trachyte.
3. Argilloid trachyte.
4. Hyaline trachyte.

Sub-group B. Hornblendic trachytes.
5. Hornblendic trachyte.
6. Augitic trachyte.
7. Phonolite.
8. Trachytic obsidian.

SUB-BASIC SERIES—PROPYLITE AND ANDESITE.

Sub-group 1. Hornblendic propylite.
2. Augitic propylite. (?)
3. Quartz-propylite.
4. Hornblendic andesite.
5. Augitic andesite.
6. Dacite, or quartz-andesite.

BASIC SERIES—BASALTS.

Sub-group 1. Dolerite.
2. Nepheline-dolerite.
3. Basalt.
4. Leucite-basalt.
5. Nepheline-basalt.
6. Tachylite.

The fifth chapter is entitled "Speculations concerning the causes of volcanic action." The author propounds a very ingenious trial hypothesis, by which he believes the sequence of volcanic phenomena throughout at least the Rocky Mountain region may be explained. He assumes that volcanic phenomena are brought about by a local increase of temperature within certain subterranean horizons. But, as he himself admits, this way of putting the case brings us no nearer to what may be the ultimate cause of such a local increase of temperature. He seeks to prove that all the phenomena of volcanic action point to local excitation, and that the observed order of appearance of lavas is what on this view might theoretically be anticipated. It would be beyond the necessary limits of this article to follow him into the details of his argument. But one or two points may be briefly referred to. He regards lavas as mainly derived not from primeval subterranean magmas, but rather from the fusion of such rocks as the crystalline schists and sedimentary formations. In the mechanics of eruptions he believes that the outpouring of lava does not arise from the expansion of vapors absorbed within the molten magma, but is merely a hydrostatic problem of the simplest order—the lava being forced out by the weight of the rocks overlying its subterranean reservoirs.

According to this hypothesis two preliminary conditions are requisite for an eruption of lava—the rocks must be fused and their density in the molten state must be less than that of the overlying rocks. The author regards the observed order of appearance of the lavas to be determined by their relative density and fusibility, the more siliceous requiring a higher temperature to fuse them, and the more basic, though less refractory, demanding a higher temperature to give them such a diminution of density as will permit them to be erupted. At an early stage of eruption he holds that the acid rocks may be light enough to be ejected, but are not yet melted, while the basic rocks may be melted, but must await further expansion by access of heat before they are capable of being poured forth. Hence some intermediate rock will be selected as the first to issue, and this rock the author believes to be propylite. A further increase of temperature produces hornblendic andesite and trachyte, and so on to the rhyolites, and finally the basalts. All rocks more basic than propylite are stated to present evidence of superfusion; these rocks, according to the theory, being those which possess so high a density as to demand a much greater accession of heat than that required for mere fusion, in order that they may become lighter than the overlying crust, and thus be erupted. Basalt, in particular, is cited as an example of a superfused rock.

The author tacitly assumes that the density of a lava at the time of its outflow is necessarily less than that of the rocks through which it ascends, otherwise it could not be erupted. It is a pity that no experimental demonstration of this assertion was given, for it forms so fundamental a postulate in the hypothesis. But even on the supposition that the lava is forced out by the descent of heavier overlying rocks, what ought to be found as proof of this action? Ought we not to meet with abundant evidence of subsidence at volcanic foci? Every mass of lava derived from the local fusion of rocks at no great depth beneath the surface, and driven out by the weight of rock overlying it, should have an accompanying and proportionate subsidence of the crust over the site of its source. Occasional proofs of collapse at volcanoes have long been known, indeed, but admit of other explanation, such as "evisceration," to use Mr. Mallet's phrase. Instead of subsidence, the emission of volcanic material has generally been accompanied with upheaval. Captain Dutton's own magnificent plateaus of Utah should furnish copious proofs of a sinking or sagging of the nearly horizontal strata around the eruptive vents. But there is no trace of any structure of this kind in his instructive and carefully-drawn sections.

Again, the alleged superfusion of the basic rocks can hardly be admitted upon the evidence here brought forward in its support. The fact that thin streams of basalt have had a greater liquidity and have retained it for much greater distances than the acid lavas has long been recognized. But, as Reyer has recently suggested, it is capable of a different interpretation from that of superfusion. The author appeals also to the microscopic structure of basalt as favoring his view of former intense ignition. He cites, for example, the presence of glass particles, the absence of water-cavities, the isotropic base, the compactness and vitreous structure of this rock. But are not these characters present in far more striking development among the vitreous acid rocks, which he supposes to have had a temperature little more than sufficient for fusion? The exceptions which the author candidly admits to occur in the normal succession of lavas—basalts, for example, appearing before rhyolites, or quartz-porpylite and quartz andesite simultaneously with the

hornblendic members of their respective groups—seem fatal to the hypothesis.

From another point of view the idea that the order of emission of lavas has been determined in the way supposed presents great difficulties. The author affirms that "we must at least admit that the source of lavas is among segregated masses of heterogeneous materials," and he supposes that "this arrangement would be well satisfied by a successecession of metamorphic strata (gneiss, hornblendic and augitic schist) resting upon a supposed primitive crust or magma having a constitution approximating that of the basaltic group of rocks." But every known mass of metamorphic strata presents endless interstratifications of very various materials. By what process of selection are the elements of these diverse rocks grouped successively into definite volcanic compounds? How is it that out of the simmering subterranean broth just so much silica and alumina as are needed for one type are ladled out at one time, while a careful hand is kept on the lime, alkilies, and iron-oxides, only the right proportion being dealt forth for each lava?

The remarkable persistence of type among the different species of lava all over the world has long been recognized. It is not easy to see how this persistence should exist, nor why there should not be far more varieties of lava and transitional grades between the varieties, if they are due to the local melting up of various masses of heterogeneous materials within the crust.

The volume is illustrated by a series of heliotype plates, from photographs taken in the course of the survey, representing some of the more remarkable external forms assumed by the sedimentary and volcanic rocks. The atlas contains a valuable series of topographical and geological maps. Among these a relief-map of the plateaus, on the scale of five miles to an inch, is specially instructive. There are likewise two plates of sections, which bring before the eye in a clear and concise form the structural details of the region. In point of execution the plates of the atlas are altogether admirable. In his preface Captain Dutton states that he undertook the task of exploration assigned to him with considerable diffidence in his ability to accomplish it. He must be congratulated on having achieved a signal success. His work bears everywhere marks of the most conscientious and painstaking industry, great acuteness of observation, and not a little literary skill in the marshaling and presentation of the facts observed. Let us hope that the arrangement by which he was enabled to exchange the routine duties of an army officer for geological field work may be prolonged, and that in further prosecution of his explorations in the West he may live to issue other volumes as interesting and valuable as that which is noticed here.

ARCH. GEIKIE.

# APPENDIX 21.

## REPORT ON THE SPENCER LINE-THROWING GUN FOR LIFE-SAVING PURPOSES, BY LIEUTENANT D. A. LYLE, ORDNANCE DEPARTMENT.

(Four Plates.)

CONTENTS.



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## THE SPENCER LINE-THROWING GUN FOR LIFE-SAVING PURPOSES.

### I.—SPENCER GUN.

(Plate I.)

#### 1.—*Description.*

The Spencer line-throwing gun is a smooth-bore, and consists of: 1, the body; 2, the trunnion ring; and 3, the breech-plug or fermeture.

The body is made of low steel, forged solid, and afterward bored out. The exterior of the body is divided into three principal parts, viz, the first reinforce, the second reinforce, and the chase.

The *first reinforce* is a frustum of a cone with the larger base turned toward the muzzle of the gun.

The *second reinforce* is a short frustum, generated by revolving about the axis a convexo-concave line whose middle point touches continually a circle having its center on, and its plane perpendicular to, the axis. This reinforce conjoins the first reinforce and the chase.

The *chase* is a frustum of a cone, terminated in front by the face of the piece without swell of the muzzle or a muzzle-band.

The *trunnion ring* is a cylindrical ring of wrought iron, which embraces the first reinforce near its rear end. This ring bears the trunnions, which are forged solid with the ring, and then turned down and properly aligned.

The *breech-plug* is made of low steel. It is divided into two symmetrical parts by a meridian plane, which is horizontal when the fermeture is in position for firing. One of the halves has four dowel pins, two on each side, that fit into corresponding holes in the other half. These dowels or pins serve to preserve the relative positions of the parts when put together. The front end of the breech-plug, as a whole, is recessed to form the small hemispherical chamber that terminates the bore.

The axial portion of the breech-plug is cut away, forming a funnel-shaped cavity connecting with the chamber at its forward and smaller end. The bounding lines of this cavity, as seen in the longitudinal section, are curves, convex toward the axis of the bore prolonged. The hole through the fermeture is made of this form to guide the line as it passes through the bore of the gun and prevent cutting it off. The head of the fermeture, or part which projects beyond the posterior terminal plane of the gun, is slightly rounded for the same reason. Two holes perpendicular to the axis are bored in this basal projection to receive the cylindrical projection on the spanner-wrench used to close the fermeture. The cylindrical exterior of the body of the breech-plug is divided into eight equal parts, four sectors being armed with sectional screw-threads and four being blanks. The sectional screws and blank spaces alternate. The rear end of the bore of the gun is counterbored, and has sectional screw-threads and blanks to correspond with those in the breech-plug. The plug is inserted by turning it to the left until the threads on the block come opposite a blank space in the gun, then press the plug forward until it reaches the bottom of the counterbore, when an eighth of a turn to the right with a spanner-wrench engages the threads on the block with the corresponding ones on the inner surface of the counterbore, and brings the block firmly to its seat, at the same time locking the system. To withdraw the plug, give it an eighth of a revolution to the left, and *pull out* the plug. The vent is perpendicular to the axis of the bore, and is placed 1″.6 in front of the trunnion ring.

It is obvious that the gun has a large muzzle preponderance.

By an error of the draughtsman, the sectional screw-threads and blank spaces have been interchanged in Figs. 3 and 4, Plate I.

### 2.—*Principal dimensions.*

| | Inches. |
|---|---|
| Total length of gun | 36.2 |
| Length of body | 35.2 |
| First reinforce, length | 16.9 |
| Diameter, rear end | 5.4 |
| Diameter, front end | 5.5 |
| Second reinforce, length | 1.0 |
| Diameter, rear end | 5.5 |
| Diameter, front end | 4.8 |
| Chase, length | 17.3 |
| Diameter at rear end | 4.8 |
| Diameter at muzzle | 3.7 |
| Trunnion ring, length | 2.5 |
| Interior diameter, a little greater than | 5.4 |
| Thickness | 1.0 |
| Trunnions, length | 2.5 |
| Diameter | 2.0 |
| Distance between faces of trunnions | 12.4 |

| | Inches. |
|---|---|
| Distance between rim-bases | 7.4 |
| Distance from rear end of body to trunnion ring | 2.4 |
| Bore, total length, exclusive of chamber | 30.1 |
| Diameter | 2.8 |
| Chamber, depth or radius | 1.3 |
| Total length of bore, including chamber | 31.4 |
| Diameter of vent | 0.2 |
| Length of counterbore in breech | 5.1 |
| Breech-plug, total length | 6.1 |
| Exterior diameter of base | 4.5 |
| Diameter of body over screw-threads | 3.1 |
| Diameter of body over blanks | 2.9 |
| Number of screw-threads | 17. |
| Funnel-shaped cavity, length | 4.8 |
| Smaller diameter | 0.5 |
| Largest diameter | 3.6 |

## II.—Gun-carriage.

(Plate II.)

### 1.—*Description.*

The carriage or bed for the Spencer gun is made of 2-inch plank planed to a thickness of 1″.8. A plank of the same thickness is placed between the cheeks, forming a bottom. The rear ends of the cheeks and bottom board are curved upward to allow the carriage to slide readily to the rear when fired. This also obviates the danger of upsetting and of entangling the line.

The cheeks are bound with wrought iron, and two handles are placed upon each side similarly to the carriage for the Lyle gun.

A wrought-iron yoke is suspended from the trunnions, and furnished with an arm of the same material which extends to the front. This arm is bent at right angles near its forward end and forms the support for the muzzle when elevated for firing. A lever on the right-hand side of the carriage actuates a clamp which binds the yoke and preserves the elevation. The cap squares are detachable and are confined by means of keys. Three holes are bored through the bottom board to receive recoil pins intended to be driven into the sand or earth. These holes are placed triangularly. The recoil bolts are two feet long and were designed to take up the recoil, but were abandoned by the inventor before the official trials.

### 2.—*Principal dimensions.*

| | Inches. |
|---|---|
| Length of carriage | 36.0 |
| Width of cheeks | 8.4 |
| Distance from axis of trunnions to rear end of carriage | 23.85 |
| Total length of gun and carriage | 55.4 |
| Total weight of gun, carriage, and bolts | 233 pounds. |

## III.—Projectiles.

### 1.—*Description.*

(Plate III. Figs. 1—5.)

The projectiles are made of cast iron. They are cylindrical in form, with short ogival points. The rear ends are rounded off. An axial hole

is drilled in the base of the shot to receive the base-screw, used to connect the projectile with the spiral spring to be hereafter described.

Three sizes of projectiles were made, differing only in length and weight. These sizes are designated as Nos. 1, 2, and 3.

2.—*Base-screw.*

(Plate III. Figs. 8 and 9.)

The base-pin or screw is slotted longitudinally for a little more than two-thirds of its length. This slot extends from the rear end forward to the anterior extremity of the exterior screw-thread. A cylindrical hole whose axis is coincident with that of the base-screw is pierced entirely through this screw. The rear portion of this hole is counterbored to enlarge it, while the forward part has a female screw-thread (not shown in drawings) tapped upon its interior surface. The exterior of the base-screw is divided into three parts—1, the square; 2, the screw-thread; and 3, the tenon.

The first is for the application of the wrench used to screw it into the slot. The screw-thread is tapering, being larger at the rear end. This taper in connection with the longitudinal slot causes the base-screw to act as a vise or clamp upon the wire tang of the spiral spring. This tang occupies the axial cavity of the screw when the latter is turned into the cylindrical hole in the base of the projectile.

3.—*Spiral spring.*

(Plate III. Figs. 1 and 7.)

This spring is made of strong steel wire. The middle portion of the steel rod is coiled in a close helix of the same diameter as the projectile. The end coils are bent inward until the front and rear tangs are in the prolongation of the axis of the spring. Threads are cut upon the extremities of the tangs. The forward tang screws into the base-screw, and the rear tang into the head of the compound sleeve that serves to attach the shot-line to the projectile. A brass valve or gas-check is placed upon the rear tang or tail just in rear of the coiled spring. This closes the aperture in the bottom of the chamber and prevents the escape of gas when the piece is fired.

4.—*Compound sleeve.*

(Plate III. Figs. 10—13.)

This sleeve is composed of two parts, the body and the head. The latter is perforated longitudinally and has screw threads cut upon both its exterior and interior surfaces. The exterior thread engages the female thread in the body and the interior one is screwed on the rear tang of the spiral spring. The body is perforated in a similar manner to the head in order to admit the end ot the shot-line. The forward portion of this cavity is counterbored to receive the end of the line after being enlarged by the insertion of the conical screw, which spreads the yarns of the line and secures it to the sleeve by wedging in the throat of the counterbore. After the conical screw is inserted in the end of the line and the latter drawn down until it wedges in the cavity, the head is screwed in and the sleeve is ready to be attached to the projectile. Two flat surfaces are cut upon opposite sides of both body and head to engage the wrenches used in assembling.

### 5.—*Conical screws.*

(Plate III. Fig. 14.)

The form of these screws is indicated by the name. They are made of brass wire. Threads are cut upon the points, and a slot in the heads to receive the blade of a small screw-driver.

### 6.—*Sabots.*

(Plate III. Figs. 6 and 7.)

The sabots are made of soft wood and accurately fit the bore of the gun. They are made in two pieces, as shown in the figure, so as to be readily placed in position when loading. They are pierced centrally by a hole large enough to embrace the projecting end of the base-screw. They are placed in rear of the projectile and in contact with its base. The sabots are intended to obviate the windage of the projectile.

### 7.—*Cartridge-bag.*

(Plate III. Fig. 7.)

This is made of serge or other woolen material, and must be long enough to allow the choke to be made some distance above the powder. If not so made it will not enter the spiral spring, as the bending in of the end coils and the projection of the tangs render it a very difficult matter to insert the cartridge even when loosely tied.

### 8.—*Principal dimensions and weights.*

| | Inches. |
|---|---|
| Diameter of projectiles | 2.75 |
| Depth of base-screw hole | 2.5 |
| Length of projectiles, Number 1 | 16.3 |
| Number 2 | 14.1 |
| Number 3 | 10.3 |
| Weight of projectiles, Number 1 | 24 pounds. |
| Number 2 | 20.5 pounds. |
| Number 3 | 15.5 pounds. |
| Base-screw, total length | 2.75 |
| Diameter of axial cavity { Screw-thread | 0.20 |
| Diameter of axial cavity { Counterbore | 0.25 |
| Square, length | 0.35 |
| Side | 0.50 |
| Screw, length | 1.55 |
| Diameter | 0.65 |
| Blank tenon, length | 0.85 |
| Diameter | 0.55 |
| Spiral spring, total length | 17.85 |
| Length of coils | 6.00 |
| Diameter of coils | 2.75 |
| Forward tang, length | 3.25 |
| Length of screw-thread | 1.25 |
| Rear tang, length | 8.60 |
| Length of screw-thread | 0.70 |
| Diameter of wire | 0.25 |
| Valve, total length | 1.00 |
| Greatest diameter | 0.75 |
| Number of coils | twenty. |
| Compound sleeve, head, length | 1.10 |
| Diameter of screw | 0.40 |
| Body, length | 2.00 |
| Greatest diameter | 0.50 |

| | Inches. |
|---|---|
| Conical screws, length | 1.05 |
| Diameter of base | 0.20 |
| Sabots, diameter | 2.80 |
| Thickness | 1.00 |
| Diameter of axial hole | 0.75 |

## IV.—IMPLEMENTS.

(Plate II.)

### 1.—*Spanner-wrench.* (*Fig.* 3.)

This wrench is made of wrought iron. The handle is round while the curved portion is rectangular in cross-section. Near the curved end on the concave side is a cylindrical projection which enters one of the holes in the breech-block when in use. This wrench is used to lock and unlock the breech mechanism.

### 2.—*Piercing-awl.* (*Fig.* 4.)

This sharp awl is designed to pierce the end of the shot-line longitudinally for the reception of the conical brass screw which wedges the line in the sleeve. The awl is lozenge-shaped in cross-section and has an ordinary wooden handle.

### 3.—*Screw-driver.* (*Fig.* 5.)

This tool is formed from a flat piece of steel and is used for setting the conical screws in the openings made by the awl.

### 4.—*Assembling wrenches.* (*Fig.* 6.)

There are two of these, made of sheet-steel. They are used simultaneously in assembling the compound sleeve. One holds the body of the sleeve firmly while the other is used to turn in the head. An ordinary rammer is used for cleaning, and a lanyard for exploding the friction primer.

## V.—METHOD OF LOADING.

The method given by the inventor lacks practicability, but it is deemed best to let him describe it in his own words. Appended to this report will be found a copy of the printed specifications forming part of his letters patent. The specifications are given in full and accompanied by a copy of the drawings forming part thereof. It will be seen by consulting the foregoing description and plates and comparing them with those of the inventor that the apparatus presented differs considerably from that indicated in the patent, though not vitiating any of the claims for the patented combinations.

## VI.—ELEVATION.

From the manner of construction it is impossible to obtain much range in the elevation of the piece. When the carriage is on a horizontal plane and the gun has an elevation of about 16°, the axis of the bore prolonged will just touch the rear edge of the bottom board. With 25° elevation the axis produced will pierce the bottom board about 8″.5 in front of the rear end.

Placed upon a shelving beach, dipping 16° or more toward the water, great difficulty would be experienced in obtaining the necessary elevation. If the beach shelved just 16° and the axis of the gun had the

same inclination, 16° to the bottom of the carriage, this axis would be horizontal when placed in position for firing. The greater the angle of elevation of the gun the greater will be the angular change of direction of the line in passing from the faking-box and out through the gun. The greater this change of direction is, the greater will be the danger of cutting off or breaking the shot-line.

## VII.—ADVANTAGES CLAIMED BY THE INVENTOR.

The inventor asserts that the object of his invention is "to obtain greater accuracy and a longer range in throwing life-lines." The greatest recorded range obtained with the Spencer gun of which the writer has any authentic knowledge is 255 yards, carrying a No. 7 braided line. The firing records exhibit no perceptible difference in accuracy over other methods.

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[Copy of printed record.]

## SPENCER'S LINE-THROWING GUN.

*Specification forming part of letters patent No.* 229058, *dated June* 22, 1880. *Application filed November* 1, 1879.

*To all whom it may concern:*

Be it known that I, Lewis W. Spencer, of the city, county, and State of New York, have invented a new and improved gun and projectile for throwing life-saving lines, of which the following is a specification:

The object of my invention is to obtain greater accuracy and a longer range in throwing life-saving lines.

In the accompanying drawings Fig. 1 is a longitudinal sectional elevation of my improved gun and projectile arranged for firing. Fig. 2 represents a side view of my improved breech-block for breech-loading guns. Fig. 3 represents the breech-block open for the reception of the connection between the life-line and the projectile. Fig. 4 is a cross-section of the gun, taken on line *x x* of Fig. 1. Fig. 5 represents the improved projectile and its elastic tail. Fig. 6 represents my improvements applied to a muzzle-loading gun.

Similar letters of reference indicate corresponding parts.

Referring to the drawings, A is a breech-loading gun, mounted by means of trunnions on a gun-carriage, B. In the breech *a* of the gun, back of the barrel *b*, is an internally screw-threaded chamber, *c*.

C is the breech-block, screw-threaded externally to adapt it to be screwed into chamber *c*. Breech-block C is divided longitudinally into two semi-cylindrical sections, *e e'*, which, when put together to form the block, are held together by dowel-pins *f* in section *e'* entering corresponding holes in section *e*. In each of sections *e e'*, at the longitudinal center, is a half round groove, *e''*. When the sections are placed together these grooves *e''* form a breech port, *e'''* (see Fig. 1), which coincides with the center of the bore of barrel *b*. Around the front end of this port *e'''* the breech-block is coned out to form a seat, *h*, and at the rear end the breech-block is funneled out, as at *i*, so that the line can run freely into port *e'''*. The object of making the breech-block in two parts is to facilitate the loading of the gun after the life-line and projectile are spliced together, the division of the breech-block permitting the splicing to be laid through the port *e'''*, so that the coiled life-line can be connected directly with the projectile, and it is only necessary to

put the two sections together and screw the breech-block into the gun, instead of having to splice the line to the projectile after loading.

D is the elongated projectile which I use with my gun. To the butt *j* is attached one end of an elastic metal tail, *k*. Near the free end *l* of the elastic tail an ovoid valve, *m*, is fixed to said tail, which serves to close the inner end of the port *e'''* in the breech. The tail *k* is made of a material that can be coiled into a tight spiral without breaking, and which will resist the action of the exploded gunpowder.

Underneath the gun is a plate, E, suspended by ears *n* from the trunnions *n'* of the gun. The forward end *o* of plate E is turned up at right angles so as to bear against the under side of the barrel *b*. Underneath the rear end of plate E is a curved arm, F, with a slot, *p*, through which is passed the end *q* of a set-screw passed through the side of the gun-carriage B. By means of plate E the muzzle of the gun is held at any required height to obtain the proper range.

The manner of using the gun and projectile is as follows: The projectiles are prepared and kept in readiness for use by splicing the end *l* of the elastic tail *k* to the free end of the life-line *l'*, which is coiled in a box in the usual manner. The breech-block C is withdrawn from the gun and opened for the insertion of the line. The projectile D is inserted into the barrel *b* through the breech *a*, and the elastic tail *k* is coiled into a close hollow spiral of the same diameter as the projectile, and this hollow spiral is passed into the barrel behind the shot in the manner shown in Fig. 1. A bag of powder, *r*, is then inserted within the spiral formed by the tail *k*, the end *l* beyond the valve *m* is laid in the channel *e''*, and the two parts of the breech-block being put together, said block is screwed into the breech, and the valve *m* is drawn into the the concave seat *h* so as to close the port *e'''* and prevent the backward escape of gas.

When the gun is fired the shot passes straight out of the gun, the elastic tail *k* uncoils, and the life-line is drawn by the tail through the port *e'''* and barrel *b* behind the shot, which is thus enabled to keep straight on its course without turning or reversing its position after leaving the gun, as is the case in the use of the common method when the life-line is attached to the shot and passed into the gun from the muzzle. The result of my improvement is, that a longer range and greater accuracy are obtained.

In Fig. 6 is shown a muzzle-loader. Herein the port *e'''* for the end of the elastic tail is made directly through the breech, and at the rear end is funneled out, the same as in the breech-block C. In this construction it is, of course, impossible to splice the elastic tail and life-line before loading. Consequently the end *l* of the tail is attached to a needle, which is thrust through the barrel *b* and thence through port *e'''*, and the end *l* having been by this means drawn through the breech, the said end is spliced to the life-line *l'* and the valve *m* is drawn down to its seat *h*.

In loading, the powder is first placed in the gun from the muzzle, the tail *k* is coiled, as before, and, having been inserted in the gun, the shot isalso placed in the muzzle and rammed home, and the gun is fired as before.

It will be readily seen that by my improvement the projectile is delivered from the gun without other retardation than that caused by the weight of the life-line, whereas by the ordinary method, when the life-line is fired out of the gun ahead of the projectile, the weight of the line compels the projectile to reverse or turn end for end, and the consequence is a very great retardation of the projectile's speed.

The tail *k*, in addition to serving as an elastic connection between the shot and the life-line, serves also as a guide for holding the shot on its course, and thus materially increases the accuracy of the shooting.

By applying the tail *k* to elongated projectiles I am enabled to use such projectiles with smooth-bore guns for all purposes, and to obtain thereby as great accuracy as is now obtained with rifled ordnance and a much longer range.

Having thus described my invention, I claim as new and desire to secure by letters patent—

1. In combination with the barrel *b*, the breech-block C, provided with a central port *e''*, valve-seat *h*, and funneled entrance *i*, as and for the purpose substantially as described.

2. In combination with the projectile D, the elastic tail *k* and valve *m*, substantially as described.

3. In combination with the projectile D, the elastic tail *k*, valve *m*, and *l* for the attachment of the life-line, substantially as described.

LEWIS W. SPENCER.

Witnesses:
W. C. DONN.
C. SEDGWICK.

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### LIST OF PLATES.

#### EXPLANATIONS.

*(Plate I.)*

Fig. 1. Longitudinal section of the Spencer line-throwing gun:
- A. First reinforce.
- E. Second reinforce.
- G. Chase.
- R. Trunnion ring.
- D. Breech-block.
- B. Bore.
- C. Chamber.
- F. Funnel-shaped cavity.
- V. Vent.

Fig. 2. Plan of Spencer line-throwing gun.
- A. Body of gun.
- D. Breech-block.
- R. Trunnion ring.
- T. Trunnions.
- V. Vent.

Fig. 3. Front elevation of breech-block.
Fig. 4. Cross-section of gun in rear of trunnions.
Fig. 5. Front elevation of gun.

*(Plate II.)*

Fig. 1. Side elevation of Spencer line-throwing gun and carriage.
Fig. 2. Front elevation of same.
Fig. 3. Spanner-wrench.
Fig. 4. Piercing awl.
Fig. 5. Plan and elevation of screw-driver.
Fig. 6. Plan and elevation of small wrenches, only one shown (wrenches are of the same size).

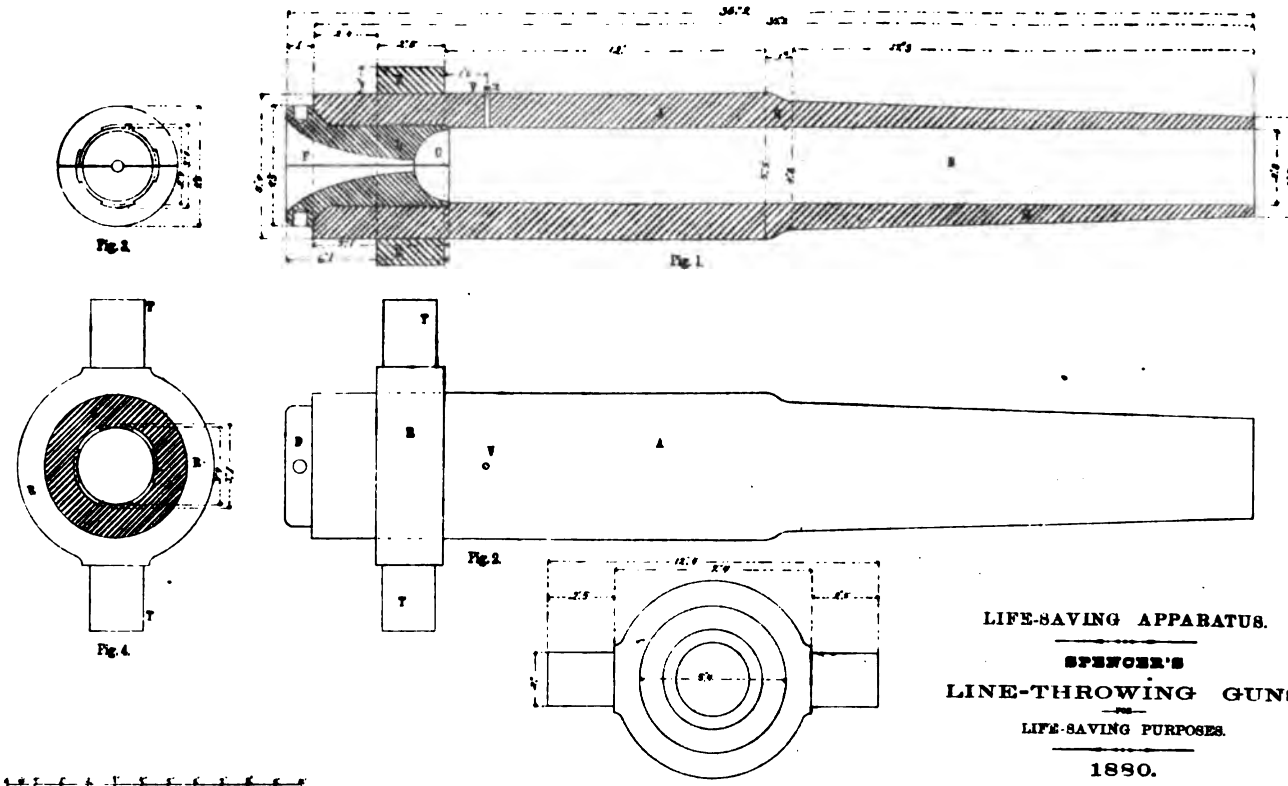
Fig. 7. Showing relative positions of gun before and after firing, showing position of line after firing (range distorted).
A. Position of gun and carriage before firing.
B. Position of gun and carriage after firing.
C. Position of faking-box.
D. Position of projectile after firing.
E. Position of shot-line after firing.

(*Plate III.*)

Fig. 1. Side elevation and partial section of Spencer life-saving projectile No. 1, showing arrangement of parts when assembled:
B. Base-screws.
A. Front tang of spiral spring.
S. Coils of spiral spring.
V. Valve or gas-check.
C. Rear tang or tail of spiral spring.
Fig. 2. Rear elevation of projectile No. 1.
Fig. 3. Side elevation and partial section of Spencer life-saving projectile No. 2, without base screw or spiral spring.
Fig. 4. Rear elevation of projectile No. 2.
Fig. 5. Side elevation and partial section of Spencer life-saving projectile No. 3.
Fig. 6. Plan and elevation of wooden sabot.
Fig. 7. Longitudinal section of Spencer line-throwing gun, showing arrangement of parts when loaded with projectile No. 1.
A. Body of gun.
D. Breech-block.
V. Vent.
B. Projectile No. 1.
G. Sabot.
S. Spiral spring.
C. Cartridge.
E. Valve or gas-check.
F. Compound sleeve.
L. Shot-line.
Fig. 8. Rear elevation and longitudinal section of base screw.
Fig. 9. Side elevation of base screw.
Fig. 10. Longitudinal section of compound sleeve.
Fig. 11. Rear and side elevations of body of sleeve.
Fig. 12. Front and side elevations of head of sleeve.
Fig. 13. Longitudinal section of body of sleeve, showing the shot-line and conical screw in position.
Fig. 14. Side elevations of two forms of conical screws.

*Plate IV.*

Enlarged copies of drawings of Spencer line-throwing gun, &c., taken from the specifications accompanying letters patent.
Fig. 1. Longitudinal section of Spencer rifled gun and carriage.
Fig. 2. Side elevation of breech-block.
Fig. 3. Plan of two halves of breech-block.
Fig. 4. Section of gun.
Fig. 5. Side elevation of rifle projectile and spiral spring.
Fig. 6. Longitudinal section of smooth-bore gun.




LIFE-SAVING APPARATUS.

SPENCER'S

LINE-THROWING GUNS

FOR

LIFE-SAVING PURPOSES.

1880.

PLATE II.

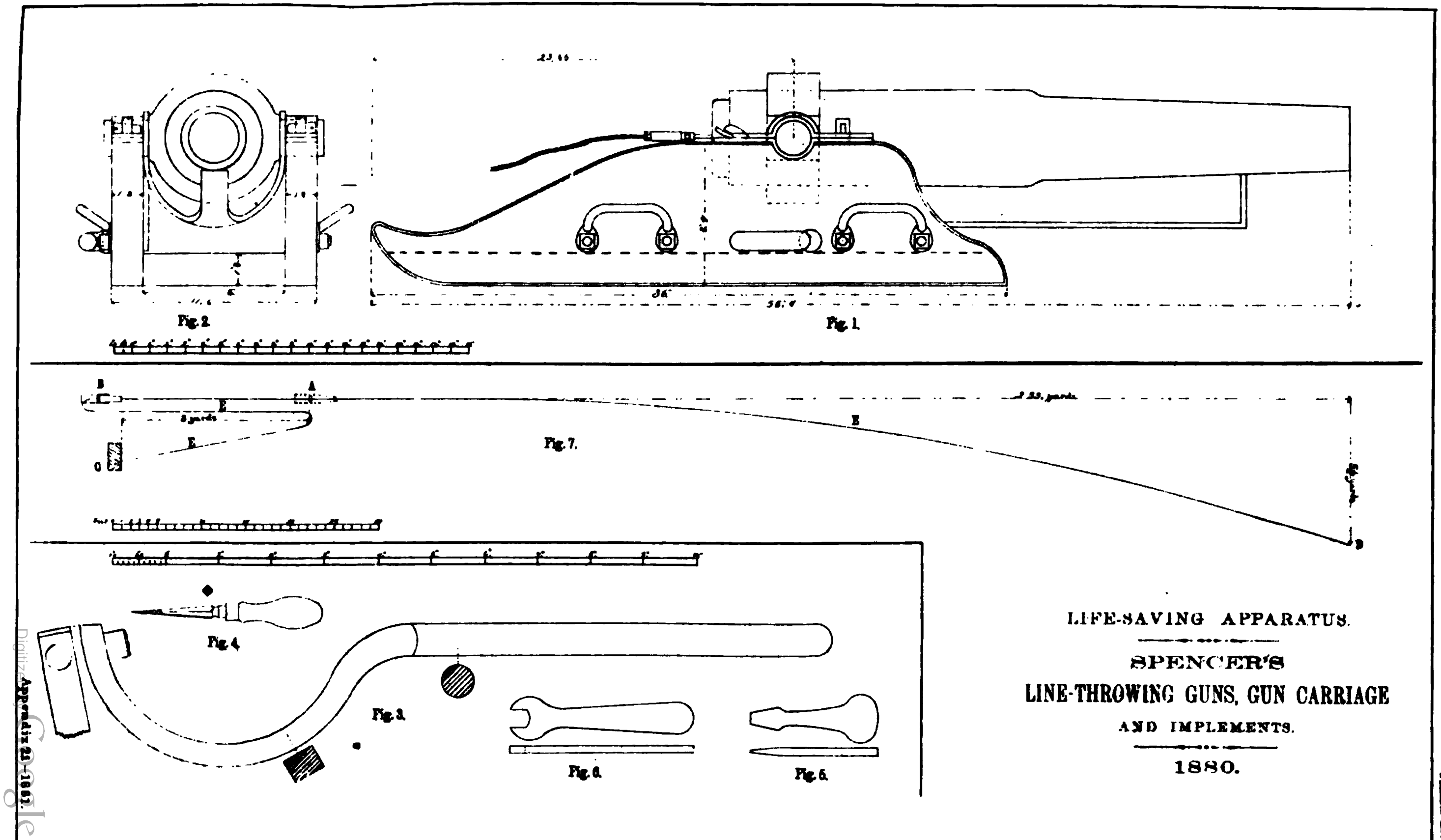
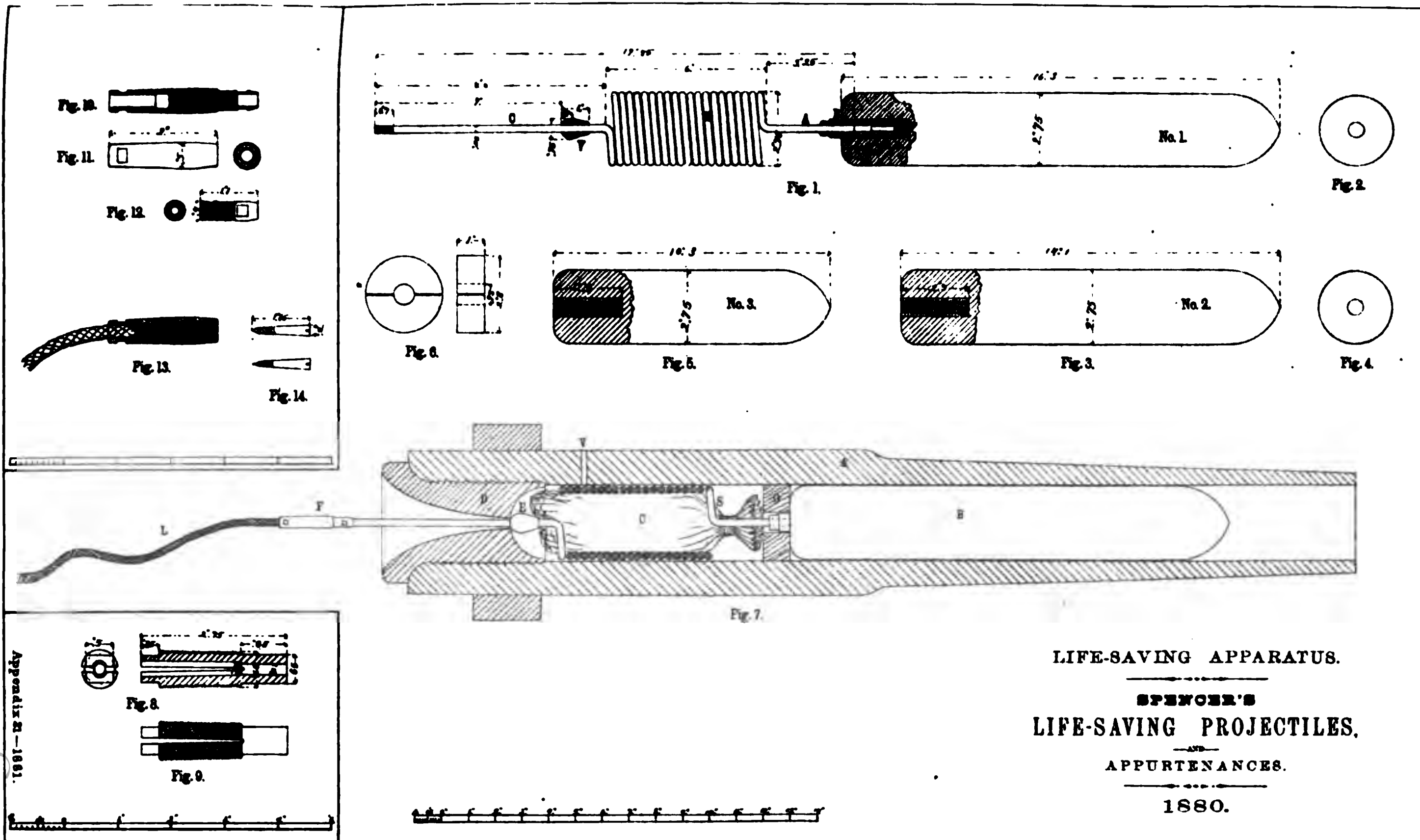


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
LIFE-SAVING APPARATUS.
SPENCER'S
LINE-THROWING GUNS, GUN CARRIAGE
AND IMPLEMENTS.
1880.




LIFE-SAVING APPARATUS.

SPENCER'S

LIFE-SAVING PROJECTILES,

AND

APPURTENANCES.

1880.

Appendix 21—1881.

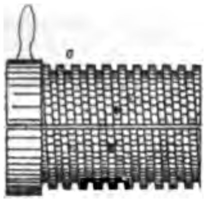


Fig. 2.

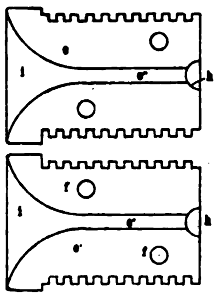


Fig. 3.

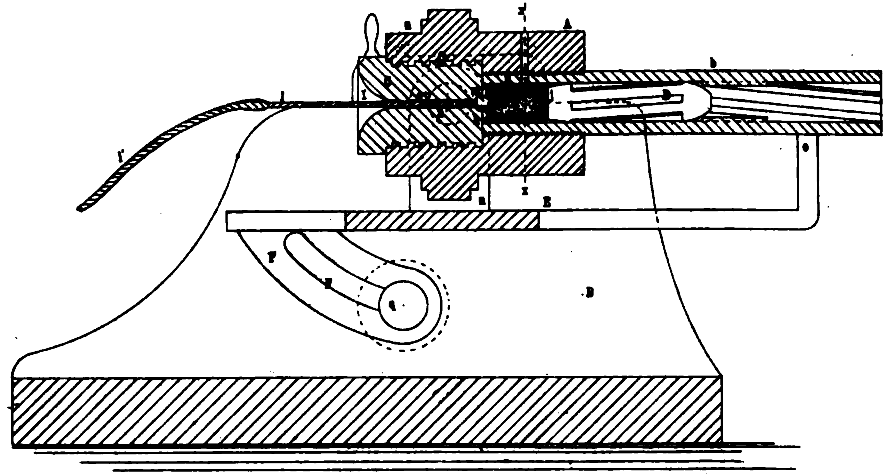


Fig. 1.

Fig. 5.

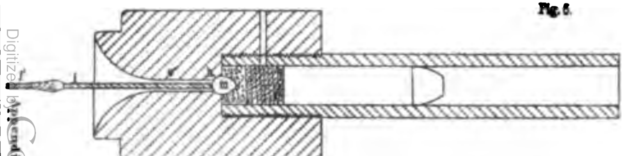


Fig. 6.

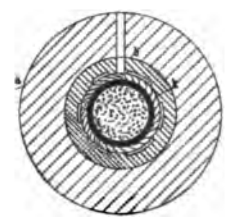


Fig. 4.

LIFE-SAVING APPARATUS.

SPENCER'S

LINE-THROWING GUNS & PROJECTILES,

As shown in his drawings for Letters Patent.

JUNE 22, 1880.

# APPENDIX 22.

## THE PRACTICAL APPLICATION OF BARTLETT'S FORMULAS TO PROBLEMS IN GUN CONSTRUCTION.

BY CAPT. GEORGE W. M'KEE, ORDNANCE DEPARTMENT.

DECEMBER, 1880.

SIR: I have the honor to forward a résumé of Prof. W. H. C. Bartlett's memoir, entitled "Strains on Rifled Guns, &c."* The exhaustive and admirable analysis by which Professor Bartlett deduces his formulas is followed by me identically as far as possible, but, as a different character of twist is here discussed, corresponding changes in the mathematics of Part I have become necessary. I have been careful to preserve the Professor's premises, reasoning, and notation, and have quoted his exact language throughout in so far as it is conformable to the case in point.

Professor Bartlett, in introducing his subject, remarks:

The general introduction of the rifled gun into the military service has made an epoch in the art of war. The great range, accuracy of fire, and increased penetrating power of the missiles of these guns have greatly expanded the dimensions of defensive works on land and changed materially the construction and character of our military marine. Such important results afford strong temptation to push the means by which they are obtained beyond the limits of prudence, and instances of disaster have created the impression that, in some cases, these limits have already been passed.

The rifled gun is not only subjected to the usual lateral strain of an ordinary smooth-bore, but also to a strain in the direction of its length and one of torsion around its axis; and doubts have been expressed whether these strains, simultaneously applied and oft-repeated, may not prove an overmatch for the endurance of the material of which this kind of gun is made. Such doubts are to be confirmed or dispelled only by numerical estimates of the strains, and the purpose of the present paper is to construct, upon principle, a set of formulas by which these estimates may be made. Many rifled guns have failed; but the same may be said of all guns, smooth and rifled; and the question is, are these failures unavoidable in the rifle?

A good gun can only result from the principles of physics, rightly applied by the rules of mechanics. Of course such a gun may come from accident, but the chances are so adverse as to make it highly improbable. Bad guns must ever fail; good ones may and often do fail from improper treatment. If the missile clog, explode in the bore, be not rammed home,† or the powder partake of the character of a fulminate in quickness, the best guns must yield. The laws of matter are immutable. No gun can stand everything; and yet the failure of a good gun from causes which would break any gun is as likely to destroy confidence in all guns of the same kind as the failure of a bad one under legitimate tests, and just as likely to produce a prejudice as a well-founded conviction. It is, therefore, quite as important to know how to treat guns as to know how to make them. The circumstances attending the failure of a gun are rarely ever known, and the verdict of those charged with the investigation of the causes of failure is almost always tainted with uncertainty. * * *

As before remarked, * * * all rifled guns are subjected to three strains. The first stretches in the direction of the circumference, the second in the direction of the length, and the third twists around the axis. The object is to find the second and third in terms of the first. The first being known from experiment, the latter become known. The known shape and dimensions of the guns, and the strength of the material of which they are made, complete the requisite data, and the application of the formulas will be easy.

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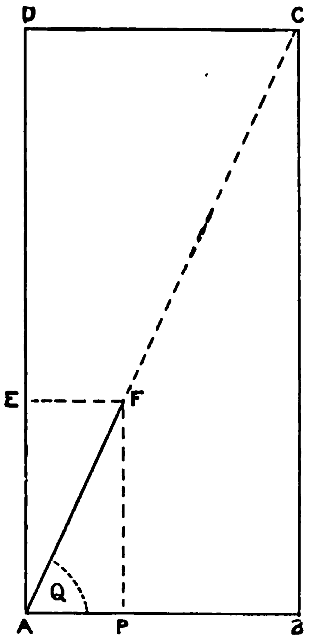
* From the Memoirs of the National Academy of Sciences, vol. I.

† There is among writers a difference of opinion on this subject, which it is not proposed to discuss here.




### LAW OF THE TWIST.

(1.) The twist is uniform, starting with nothing at a point 18 inches from the bottom of the tube and making one turn in 70 feet. The development of a groove is constructed in this wise, viz: A B is the base of a rectangle equal to the circumference of the bore, and B C the height equal to the length of a single revolution of the spiral measured on the axis of the bore. The diagonal A C represents the development of an entire revolution of the required groove. On A D lay off the distance A E, equal to the length of the rifled bore, and at E erect the perpendicular E F. A F will be the development of the groove which lies on the surface of the bore.*

### EQUATION OF THE DEVELOPED GROOVE.

(2.) Take the origin at A; A B as the axis of $X$ and A D as that of $Y$. Call the angle P A F, $Q$. Then will A P$=x$ and P F$=y$.

$$y=x\tan Q \tag{1}$$

is the equation of the line A F—the developed groove.

### EQUATION OF A HELIX OF THE GROOVE.

(3.) Now wrap the developed surface around the cylinder of the bore; denote the radius of the latter by $\nu$. Conceive a plane through the axis of the gun to revolve about that line and to start from a position in which it contains the element of the cylinder upon which the groove starts at the bottom. Denote the variable angle which this plane makes with its initial position by $\Psi$; then will

$$x=\nu\Psi$$

and equation (1)

$$y=\nu\Psi\tan Q \tag{2}$$

Denote the length of the groove in the direction of the axis by $l$, and let $n$ represent the ratio of the circumference of the bore to that portion of the same into which the entire helix is projected, or

$$n=\frac{2\pi\nu}{x}$$

Let $a$ represent the cotangent of the angle which an element of the helix makes with the axis of the gun. Then we have

$$y=ax;\ x=\nu\Psi$$

whence

$$L=y-a\nu\Psi=o$$

$$\nu=\text{constant}$$

* Benton's Ordnance and Gunnery, p. 171.

for the equations of a helix of a uniform groove, with the origin on the axis of the piece. Making $y = l$

$$a = \frac{nl}{2\pi}$$

and we have

$$\left. \begin{aligned} L = y - \frac{nl}{2\pi}\nu\Psi = o \\ \nu = \text{constant.} \end{aligned} \right\} \quad (3)$$

whence

$$\left. \begin{aligned} \nu\Psi = y\frac{2\pi}{nl} \\ \nu = \text{constant} \end{aligned} \right\} \quad (4)$$

(4.) Differentiating equation (4), dividing by $dt$, and making $\frac{dy}{dt} = V =$ velocity of the projectile, we have

$$\frac{d\Psi}{dt} = \frac{2\pi V}{\nu nl} \quad (5)$$

Substituting $y$ for $l$, differentiating again, and dividing by $dt$,

$$\frac{d^2\Psi}{dt^2} = -\frac{2\pi V^2}{\nu ny^2} \quad (6)$$

(5.) Dividing equation (5) by $2\pi$, and denoting the number of turns of the projectile in a second of time by $\upsilon$, we find

$$\upsilon = \frac{V}{\nu nl} \quad (7)$$

(6.) Denoting the distance passed over by the projectile while turning once on its axis by $d$, we have

$$d = \frac{V}{\upsilon} = \nu nl \quad (8)$$

(7.) The passage of the projectile from its place of rest to the mouth of the piece is a case of constrained motion, and the conditions of constraint are given by equation (4).

Make the following notation, viz:
P = Intensity of the force on back of the projectile in direction of axis.
M = Mass of the projectile.
I = Moment of inertia of the projectile with reference to axis of piece.
N = Normal pressure on edge of land.
$f$ = Co-efficient of friction.
$\theta$ = Angle of inclination of an element of the twist to axis of piece.
= Any indefinite arc of the helix.

Then will

$$\left.\begin{aligned}\left(\mathrm{P}-\mathrm{M}\frac{d^2y}{dt^2}\right)\cdot\sigma y-\mathrm{I}\frac{d\Psi^2}{dt^2}\cdot\sigma\Psi-f\mathrm{N}\,\sigma s=o\\ \sigma s=\nu\sin\theta\,\sigma\Psi+\cos\theta\,\delta y\end{aligned}\right\}\mathrm{A}\ *$$

which latter substituted above gives

$$\mathrm{P}-\mathrm{M}\frac{d^2y}{dt^2}-f\mathrm{N}\cos\theta\Big)\sigma y-\left(\mathrm{I}\frac{d^2\Psi}{dt^2}+f\mathrm{N}\,\nu\sin\theta\right)\delta\Psi=o$$

From equation (4) we have

$$\nu\sigma\Psi-\frac{2\pi\sigma y}{nl}=o$$

$$\sigma\nu=o$$

Multiply the first by $\lambda$, the second by $\lambda^1$, and adding to the equation above,

$$\left(\mathrm{P}-\mathrm{M}\frac{d^2y}{dt^2}-f\mathrm{N}\cos\theta-\lambda\frac{2\pi}{nl}\right)\sigma y-\left(\mathrm{I}\frac{d^2\Psi}{dt^2}+f\mathrm{N}\,\nu\sin\theta-\lambda\nu\right)$$
$$\sigma\Psi+\lambda^1\sigma\nu=o$$

whence

$$\mathrm{P}-\mathrm{M}\frac{d^2y}{dt^2}-f\mathrm{N}\cos\theta-\lambda\frac{2\pi}{nl}=o \tag{9}$$

$$\mathrm{I}\frac{d^2\Psi}{dt^2}+f\mathrm{N}\,\nu\sin\theta-\lambda\nu=o \tag{10}$$

$$\lambda^1=o \tag{10$^1$}$$

$$\mathrm{N}=\lambda\sqrt{\left(\frac{d\mathrm{L}}{\nu d\Psi}\right)^2+\left(\frac{d\mathrm{L}}{d\nu}\right)^2+\left(\frac{d\mathrm{L}}{dy}\right)^2}=\lambda\sqrt{1+\frac{4\pi^2}{n^2l^2}}\ \dagger$$

From equations (9) and (10) we have

$$\lambda=\frac{\mathrm{P}-\mathrm{M}\frac{d^2y}{dt^2}-f\mathrm{N}\cos\theta}{\frac{2\pi}{nl}}$$

$$\lambda=\frac{\mathrm{I}\frac{d^2\Psi}{dt^2}+f\mathrm{N}\,\nu\sin\theta}{\nu}.$$

* Bartlett's Mechanics, pp. 55 and 467. If the extraneous forces applied to a body be not in equilibrio, they will communicate motion to it, and will develope forces of inertia in its various elementary masses with which they will be in equilibrio; and if extraneous forces equal in all respects to these forces of inertia were introduced into the system, the algebraic sum of the virtual moments would be equal to zero.

† $\lambda$ and $\lambda^1$ are any indeterminate intensities. N, the resultant of the extraneous forces and the forces of inertia exercising a normal pressure on the edge of the land, is equal to the square root of the sum of the squares of its components in the directions of the axes of X, of Y, and of the radius.—*Bartlett's Mechanics*, pp. 219 and 223.

Equating these values, we get

$$P - M\frac{d^2y}{dt^2} - N\left[f\cos\theta + f\sin\theta\frac{2\pi}{nl}\right] - I\frac{d^2\Psi}{dt^2}\cdot\frac{2\pi}{\nu nl} = o. \tag{11}$$

$$\text{Make } a = \sqrt{1 + \frac{4\pi^2}{n^2l^2}} \tag{12}$$

Then will

$$N = \lambda\, a = \frac{I\frac{d^2\Psi}{dt^2} + fN\nu\sin\theta}{\nu}\,.\,a$$

$$N = \frac{I\frac{d^2\Psi}{dt^2}\,.\,a}{\nu(1 - af\sin\theta)}.$$

Substituting this in equation (11) we find

$$P - M\frac{d^2y}{dt^2} - I\frac{d^2\Psi}{dt^2}\left[\frac{af\left(\cos\theta + \sin\theta\frac{2\pi}{nl}\right)}{\nu(1 - af\sin\theta)} + \frac{2\pi}{\nu nl}\right] = o$$

$$\text{Make } A^1 = \frac{af\left(\cos\theta + \sin\theta\frac{2\pi}{nl}\right)}{\nu(1 - af\sin\theta)} + \frac{2\pi}{\nu nl},$$

and the above becomes

$$P - M\frac{d^2y}{dt^2} - I\frac{d^2\Psi}{dt^2}\cdot A^1 = o \tag{13$^{\text{I}}$}$$

Substituting the value of $\frac{d^2\Psi}{dt^2}$ as given by equation (6), we find

$$\frac{d^2y}{dt^2} = \frac{P + I\frac{2\pi V^2}{\nu ny^2}\,.\,A^1}{M} \tag{13$^{\text{II}}$}$$

Multiplying both members by M and subtracting from $P = P$,

$$P - M\frac{d^2y}{dt^2} = -I\frac{2\pi V^2}{\nu ny^2}\cdot A^1 \tag{14}$$

Taking the value of $\frac{d^2y}{dt^2}$ in equation $(13)^{\text{II}}$, and substituting it in equation $(13)^{\text{I}}$, we find

$$I\frac{d^2\Psi}{dt^2} = -I\,.\,\frac{2\pi V^2}{\nu ny^2};$$

Dividing by $\nu$

$$\frac{I}{\nu}\cdot\frac{d^2\Psi}{dt^2} = -I\,.\,\frac{2\pi V^2}{\nu^2ny} \tag{15}$$

Before the value of $A^1$ can be employed, it will be necessary to find $\cos\theta$ and $\sin\theta$, in functions of $y$. For this purpose we have

$$\left.\begin{aligned}\sin\theta &= \frac{\nu d\Psi}{\sqrt{\nu^2 d\Psi^2 + dy^2}} = \frac{1}{\sqrt{1+\frac{dy^2}{\nu^2 d\Psi^2}}} = \frac{\frac{2\pi}{nl}}{\sqrt{1+\frac{4\pi^2}{n^2l^2}}} \\ \cos\theta &= \frac{dy}{\sqrt{\nu^2 d\Psi^2 + dy^2}} = \frac{1}{\sqrt{1+\frac{\nu^2 d\Psi^2}{dy^2}}} = \frac{1}{\sqrt{1+\frac{4\pi^2}{n^2l^2}}}\end{aligned}\right\} \quad (16)$$

which substituted in the value for $A^1$, $a$ will disappear, and give

$$A^1 = \frac{f\left(1+\frac{4\pi^2}{n^2l^2}\right)}{\nu\left(1-f\frac{2\pi}{nl}\right)} + \frac{2\pi}{\nu nl} = \frac{nlf+2\pi}{\nu(nl-2\pi f)},$$

which substituted for $A^1$ in equation (14) gives

$$P - M\frac{d^2y}{dt^2} = -I\frac{2\pi V^2}{\nu ny^2}\cdot\frac{nlf+2\pi}{\nu(nl-2\pi f)} \quad (17)$$

(8). Denoting the weight of the projectile, in pounds, by W, and the principal radius of gyration of the projectile in reference to the axis of rotation by $k^1$, then will

$$I = \frac{W}{g}k_1^2 : \quad M = \frac{W}{g}$$

and equations (17) and (15) become

$$P - M\frac{d^2y}{dt^2} = -\frac{W}{g}k_1^2\cdot\frac{2\pi V^2}{\nu ny^2}\cdot\frac{nlf+2\pi}{\nu(nl-2\pi f)} \quad (18)$$

$$\frac{I}{\nu}.\frac{d^2\Psi}{dt^2} = -\frac{W}{g}k_1^2.\frac{2\pi V^2}{\nu^2 ny^2} \quad (19)$$

Making $A = A^1\nu$ the formulas will stand

$$A = \frac{nlf+2\pi}{nl-2\pi f} \quad (20)$$

$$P - M\frac{d^2y}{dt^2} = -\frac{W}{g}k_1^2.\frac{2\pi V^2}{\nu^2 ny^2}\cdot\frac{nlf+2\pi}{nl-2\pi f} \quad (21)$$

$$\frac{I}{\nu}\cdot\frac{d^2\Psi}{dt^2} = -\frac{W}{g}k_1^2.\frac{2\pi V^2}{\nu^2 ny^2} \quad (22)$$

(9.) Denote by C the strain in direction of circumference of the bore,

$$C = p_1 . 2\nu . (y + c), \quad (23)$$

in which $c$ is the distance from the bottom of the bore to the beginning of the groove, and $p_1$ is the pressure of gas on one square foot of surface.

At the mouth of the gun $y = l$, and the working formulas become

$$A = \frac{nlf + 2\pi}{nl - 2\pi f}; \tag{24}$$

$$P - M\frac{d^2y}{dt^2} = -\frac{W}{g}k_1^2 \cdot \frac{2\pi V^2}{\nu^2 n l^2} \cdot \frac{nlf + 2\pi}{nl - 2\pi f} \tag{25}$$

$$\frac{I}{\nu} \cdot \frac{d^2\varphi}{dt^2} = -\frac{W}{g}k_1^2 \cdot \frac{2\pi V^2}{\nu^2 n l^2} \tag{26}$$

$$C = 2p_1 \cdot \nu \cdot (l + c) \tag{27}$$

The value of $\lambda^1$ being zero, equation $(10)^1$ shows no action to draw the expanding ring of the projectile outward, on the part of the edge of the land.

Equation (23) gives the tangential or circumferential, equation (21) the longitudinal, and equation (22) the torsion strain, all expressed in pounds, and the lever arm of the latter being the radius of the bore. The strength of the gun material will readily suggest the figure and dimensions necessary to resist these strains. The strength of the material should be ascertained by careful experiments, so conducted as to subject cylinders of the metal simultaneously to the three kinds of strain, the intensities of the strains bearing to one another the proportions suggested by the formulas.

(10.) To apply these formulas it will only be necessary to find, experimentally, the value of $p_1$ with the Rodman or other plug, the value of V, for different values of $y$, with the Schultz, Boulengé, Benton, or other ballistic machine, and to compute from the known figure and dimensions of the projectile the value of $k_1$. It is assumed from Major Rodman's experiments* that the projectile acquires one-half its initial velocity at one-third the distance from the starting point to the mouth of the piece, and that the pressure is reduced to one-third at this same point. The actual velocity of the projectile at any point of the bore can be determined by electricity, and it is advisable to do this for the sake of accuracy. To determine the corresponding pressure, without mutilating the gun, is not a matter of such easy accomplishment; but Rodman's experiments so plainly warrant Professor Bartlett's assumption as to the reduction of pressure that it may be considered perfectly safe for all practical purposes.

(11.) Let us illustrate the mode of computation by applying the formulas to the case of the United States 12.25 inch muzzle-loading rifle. Taking the dimensions of the gun, the pressure of gas, and velocity and

* In Major Rodman's work, entitled "Experiments on Metals and Gunpowder," page 200, it appears that in a 42-pounder 8 pounds of powder behind a solid shot and sabot gave a pressure of the gas on a square inch, at 14 inches from the bottom of the bore, equal to 46,100 pounds; at 28 inches, 12,200; at 42 inches, 5,500; at 56 inches, 5,350; at 70 inches, 4,970; and at 84 inches, 5,700; showing a pretty rapid decrease after the projectile begins to move, and from which it may be assumed that the projectile acquires one-half its initial or maximum velocity at about one-third the distance from the starting point to the mouth of the piece.—*Professor Bartlett's Memoir*, page 8.

weight of projectile from the report of the Chief of Ordnance, 1878, the data for computation will stand:

| Feet. | Feet. |
|---|---|
| † $\nu = 0.509875.$ | $c = 1.68416.$ |
| $l = 17.246.$ | $y = 5.74866.$ |
| ‡ $n = 4.059.$ | * * * * |
| $k_1^2 = 0.11675981.$ | $\pi = 3.1416.$ |
| $g = 32.$ | $f = 0.161$ = friction between brass and wrought iron. |
| $V = \frac{1485}{2} = 742.5.$ | $W = 700.$ |
| | $p_1 = \frac{1}{3} \times 33500 \times 144 = 1608000.$ |

THE TANGENTIAL STRAIN AT ONE-THIRD DISTANCE.

Equation (23).

| | Nos. | Logs. |
|---|---|---|
| $p_1 =$ | 1608000. | 6.2062860 |
| $2\nu =$ | 1.019750. | 0.00849371 |
| $y + c =$ | 7.43282. | 0.8711536 |
| $C =$ | 12188255 pounds. | 7.08593331 |

THE TORSION AND LONGITUDINAL STRAINS AT ONE-THIRD DISTANCE.

Equation (20).

| | Nos. | Logs. |
|---|---|---|
| $nl =$ | 70 | 1.8450980 |
| $f =$ | 0.161 | $-$1.2068259 |
| $nlf =$ | 11.27 | 1.0519239 |
| $2\pi =$ | 6.2833 | 0.7981809 |
| $2\pi =$ | 6.2833 | 0.7981809 |
| $f =$ | 0.161 | $-$1.2068259 |
| $2\pi f =$ | 1.011 | 0.0050068 |
| $nlf + 2\pi =$ | 11.27 + 6.2833 = 17.5533 | 1.2443588 |
| $nl - 2\pi f =$ | 70 − 1.011 = 68.989 *ac* | 8.1612202 |
| $\frac{nlf + 2\pi}{nl - 2\pi f} =$ | 0.2544 = A | $-$1.4055790 |

Equations (22) and (21).

| | Nos. | Logs. | Logs. |
|---|---|---|---|
| $W =$ | 700 | | 2.8450980 |
| $k_1^2 =$ | 0.11675981 | | $-$1.0672934 |
| $g =$ | 32 | 1.50514998 *ac* | 8.4948500 |
| $\frac{W}{g} k_1^2 =$ | 2.554 | | 0.4072414 |

† The diameter of bore across lands $= \left\{ \begin{array}{l} 12.227 \\ 12.247 \end{array} \right.$ inches; the mean value of $\nu$ is, therefore, 6.1185 inches.

‡ The circumference at bottom of rifled bore into which the helix is projected has a diameter of 12.247 + .182 inches = diameter across lands at that point. The value of $n$ is found accordingly.

| | | | Logs. |
|---|---|---|---|
| $2\pi =$ | 6.2833 | | 0.7981809 |
| $V^2 =$ | $(742.5)^2$ | $2.8706965 \times 2$ | 5.7413930 |
| $2\pi V^2 =$ | 3463969 | | 6.5395739 |
| $\nu^2 =$ | $(0.509875)^2$ | $-1.7074638 \times 2$ | $-1.4149276$ |
| $n =$ | 4.059 | | 0.6084191 |
| $y^2 =$ | $(5.74866)^2$ | $0.7595667 \times 2$ | 1.5191334 |
| $\nu^2 n y^2 =$ | 34.8723 | | 1.5424801 |
| $\frac{W}{g} k_1^2 =$ | 2.554 | | 0.4072414 |
| $2\pi V^2 =$ | 3463969 | | 6.5395739 |
| $\nu^2 n y^2 =$ | 34.8723 | 1.5424801 *ac* | 8.4575199 |
| $\frac{I}{\nu} \cdot \frac{d^2\Psi}{dt^2} =$ | 253709 pounds. | | 5.4043352 |
| A | | | $-1.4055790$ |
| $P - M\frac{d^2y}{dt^2} =$ | 64552 pounds. | | 4.8099142 |

(12.) Let us now compute the strains when the projectile has reached the mouth of the gun. For this purpose equations (25), (26), and (27) are applicable.

Equation (27).

| | Nos. | Logs. |
|---|---|---|
| $^*p_1 =$ | 603000 | 5.7803173 |
| $2\nu =$ | 1.019750 | 0.0084937 |
| $l + c =$ | 18.93016 | 1.2771543 |
| $C =$ | 11640330 pounds. | 7.0659653 |

*     *     *     *     *     *     *

Equations (26) and (25).

| | Nos. | Logs. | Logs. |
|---|---|---|---|
| $2\pi =$ | 6.2833 | | 0.7981809 |
| $V^2 =$ | $(1485)^2$ | $3.1717265 \times 2$ | 6.3434530 |
| $2\pi V^2 =$ | | | 7.1416339 |
| $\frac{W}{g} k_1^2 =$ | 2.554 | | 0.4072414 |
| $\nu^2 =$ | $(0.509875)^2$ | $-1.4149276$ *ac* | 10.5850724 |
| $n =$ | 4.059 | 0.6084191 *ac* | 9.3915809 |
| $l^2 =$ | $(17.246)^2$ | 2.4733768 *ac* | 7.5266232 |
| $\frac{I}{\nu} \cdot \frac{d^2\Psi}{dt^2} =$ | 112759 pounds. | | 5.0521518 |
| A | | | $-1.4055790$ |
| $P - M\frac{d^2y}{dt^2} =$ | 28690 pounds. | | 4.4577308 |

* The pressure at muzzle, according to Rodman's experiments, is about one-eighth of the pressure at seat of the charge.

(13). Next compute the effective work the torsion strain performed on the projectile during the passage of the latter to the mouth of the piece. For this purpose we have equation (5):

$$\frac{1}{2}\left(\frac{d\Psi}{dt}\right)^2 = \frac{W}{2g} \cdot k_1^2 \cdot \frac{4\pi^2}{n^2 l^2 \nu^2} V^2$$

| | Logs. | Logs. |
|---|---|---|
| $V^2 = (1485)^2$ | 3.1717265 × 2 | 6.3434530 |
| $\pi^2 = (3.1416)^2$ | 0.4971509 × 2 | 0.9943018 |
| $4 = 4$ | | 0.6020599 |
| $k_1^2 = 0.11675981$ | | − 1.0672934 |
| $W = 700$ | | 2.8450980 |
| $2g = 64$ | 1.8061799 *ac* | 8.1938201 |
| $n^2 = (4.059)^2$ | 0.6084191 × 2 *ac* | 8.7831618 |
| $l^2 = (17.246)^2$ | 1.2366884 × 2 *ac* | 7.5266232 |
| $\nu^2 = (0.509875)^2$ | − 1.7074638 × 2 *ac* | 10.5850724 |
| $\frac{1}{2}\left(\frac{d\Psi}{dt}\right)^2 =$ 87273 foot-pounds. | | 4.9408836 |

The work of the torsion strain will be that required to raise 87273 pounds through a vertical distance of one foot in the time required for the projectile to pass from rest to the mouth of the gun.

(14.) To compute the work in the projectile, due to its motion of translation, we have

| | Logs. | Logs. |
|---|---|---|
| $W = 700$ pounds. | | 2.8450980 |
| $g = 32$ | 1.50514998 | *ac* 8.4948500 |
| $2 = 2$ | 0.30103000 | *ac* 9.6989700 |
| $V^2 = (1485)^2$ | 3.1717265 × 2 | 6.3434530 |
| $\frac{MV^2}{2} = \frac{W}{2g} \cdot V^2 =$ 24119646 foot-pounds. | | 7.3823710 |

(15.) The torsion strain, at one-third distance from the point of the projectile's departure to the mouth of the gun, or

| | Logs. |
|---|---|
| $T = 253709$ | 5.4043352 |
| Tangential (circumferential), or $C = 12188255$ | *ac* 2.3184018 |
| $\frac{T}{C} = 0.020816$ | − 2.3184018 |

So that the strain which twists the gun is but little more than two one-hundredths of that which acts to split it. And again,

| | |
|---|---|
| Longitudinal strain, or $L = 64552$ | 4.8099142 |
| Tangential (circumferential), or $C = 12188255$ | *ac* 2.9140666 |
| $\frac{L}{C} = 0.0052964$ | − 3.7239808 |

And the longitudinal strain is but little over five one-thousandths of that which acts to split the gun at that point.

| | Logs. |
|---|---|
| The torsion strain at mouth, or $T = 112759$ | 5.0521518 |
| Tangential (circumferential), or $C = 11640330$ | *ac* 2.9340346 |
| $\frac{T}{C} = 0.0096869$ | − 3.9861864 |

And the strain which twists the gun at the muzzle is not quite ten-thousandths of that which acts to split. And again, at the mouth of the gun,

| | | Logs. |
|---|---|---|
| Longitudinal strain, or | $L = 28690$ | 4.4577308 |
| Tangential (circumferential), or | $C = 11640330$ | *ac* 2.9340346 |
| $\frac{L}{C} = 0.0024647$ | | -- 3.3917654 |

And the longitudinal strain at the mouth of the gun is but little over two one-thousandths of the tangential, or splitting strain, when the projectile reaches that point.

(16.) The 8-inch converted rifle No. 1, experimented with by the United States Ordnance Board, has a uniform twist of one turn in forty feet. Suppose we take a gun having the dimensions of the 100-pounder (6.4-inch) Parrott rifle and apply this twist to it.

The data for the calculation will be

| Feet. | Feet. |
|---|---|
| $\nu = 0.266$ | $y = 3.61$ |
| $l = 10.833$ | * * * * |
| $n = 3.69$ | $\pi = 3.1416$ |
| $k_1^2 = 0.035378$ | $f = 0.161$ |
| $g = 32$ | $W = 101$ |
| $V = \frac{1250}{2} = 625$ | $p_1 = \frac{1}{3} \times 81000 \times 144 = 3888000;$ |
| $c = 1$ | |

and at one-third the distance from the point of the projectile's departure to the mouth of the gun we will find the longitudinal strain, or L, = 26284 pounds, and the torsion strain, or T, = 80545 pounds. At the mouth of the gun we will have the longitudinal strain, or L, = 11729 pounds, and the torsion strain, or T, = 35943 pounds. The twist of the 8-inch converted rifle (one turn in 40 feet) was selected in order to conform as nearly as possible with the twist of the 6.4-inch (100-pounder) Parrott rifle. The value of $n$ for the 8-inch rifle-twist is 3.69, and for the Parrott 3.5 thus showing that the Parrott twist completed its turn more nearly than the 8-inch in the length of the gun. The Parrott initial twist was not, however, so abrupt as the 8-inch, and therefore the inertia of the projectile in the latter case caused correspondingly greater longitudinal and torsion strains in resisting its initial motions of translation and rotation. But the inertia having been overcome, both of these strains diminished rapidly toward the muzzle, where they were less than one-half of what they were near the point of the projectile's departure. Precisely the reverse takes place with the increasing or Parrott twist. The constraint of the projectile increases as the muzzle is approached, and the inertia develops corresponding increments of longitudinal and torsion strains. Both these strains, as shown by Professor Bartlett, are at their maxima at the muzzle, and hence, although the assistance to the tangential strain is slight, may possibly be explained either a fault in construction or a tendency in the Parrott rifles to break *torsionally* at the muzzle, as evinced by the very small calibers, and the 300-pounder at Morris Island; and *longitudinally* by blowing out the breech, as invariably happens with the 200-pounder.

If we represent the tangential strain* by 100, the results of these calculations may, for comparison, be conveniently tabulated as follows:

(1.)

*Parrott* 100-*pounder* (*or* 6.4-*inch*) *rifle*.

| Twist. | Weight of projectile. | Strains at muzzle. | | |
|---|---|---|---|---|
| | | Tangential. | Torsion. | Longitudinal. |
| Increasing. | 101 pounds. | 100 | 0.1319 | 0.0381 |

(2.)

6.4-*inch rifle—one turn in* 40 *feet*.

| Twist. | Weight of projectile. | Strains at muzzle. | | |
|---|---|---|---|---|
| | | Tangential. | Torsion. | Longitudinal. |
| Uniform. | 101 pounds. | 100 | 0.4267 | 0.1393 |

(3.)

*Parrott* 100-*pounder* (*or* 6.4-*inch*) *rifle*.

| Twist. | Weight of projectile. | Strains at one-third distance. | | |
|---|---|---|---|---|
| | | Tangential. | Torsion. | Longitudinal. |
| Increasing. | 101 pounds. | 100 | 0.0717 | 0.0182 |

(4.)

6.4-*inch rifle—one turn in* 40 *feet*.

| Twist. | Weight of projectile. | Strains at one-third distance. | | |
|---|---|---|---|---|
| | | Tangential. | Torsion. | Longitudinal. |
| Uniform. | 101 pounds. | 100 | 0.8445 | 0.2756 |

(5.)

*United States* 12.25-*inch M. L. rifle—one turn in* 70 *feet*.

| Twist. | Weight of projectile. | Strains at muzzle. | | |
|---|---|---|---|---|
| | | Tangential. | Torsion. | Longitudinal. |
| Uniform. | 700 pounds. | 100 | 0.9687 | 0.2465 |

(6.)

*United States* 12.25-*inch M. L. rifle—one turn in* 70 *feet*.

| Twist. | Weight of projectile. | Strains at one-third distance. | | |
|---|---|---|---|---|
| | | Tangential. | Torsion. | Longitudinal. |
| Uniform. | 700 pounds. | 100 | 2.08 | 0.5296 |

*At one-third distance for 6.4-inch rifle, C = 9537457 pounds; at muzzle, C = 8422050 pounds.

These ratios would indicate (as remarked by Professor Bartlett in reference to the Parrott twist) that the failure of rifled guns, with reasonable twists, must be sought in some cause other than the superaddition of the pulling and twisting strains to that which acts to split the piece; and, so far as the principles of rifling are concerned, these guns may be made as safe as the common smooth-bores.

Tables 1, 2, 3, and 4 were calculated for a pressure of 81,000 pounds per square inch of bore and an initial velocity of 1,250 feet; while tables 5 and 6 were calculated for a pressure of 33,500 pounds per square inch of bore and an initial velocity of 1,485 feet.

In the first case, we find an enormous tangential strain due to the enormous pressure, and small torsion and longitudinal strains due to the small velocity.

In the second case, we find a comparatively small tangential strain due to the small pressure of the hexagonal powder, and increased torsion and longitudinal strains due to the fair velocity of 1,485 feet.

By air-spacing, the tangential strain may be still maintained constant while the torsion and longitudinal strains are further increased.

### AN INCREASING TWIST.

If $p_1$ denote the pressure of the gas on one square foot of surface, then

$$P = p_1 . \pi . \nu^2.$$

The formulas for an increasing twist are

$$A = \frac{f + \nu \frac{\pi^2}{nl} . \sin\left(\frac{1}{2}\pi . \frac{y}{l}\right)}{1 - f . \nu . \frac{\pi^2}{nl} \sin\left(\frac{1}{2}\pi \frac{y}{l}\right)}; \tag{28}$$

$$\left.\begin{aligned} P - M\frac{d^2y}{dt^2} &= A \frac{\pi^2 . k_1^2}{\nu . n . l . g} . \sin\left(\frac{1}{2}\pi\frac{y}{l}\right) . \\ &\frac{p_1 . g . \pi . \nu^2 + W . V^2 . \frac{\pi}{2l} . \cot\left(\frac{1}{2}\pi . \frac{y}{l}\right)}{1 + A k_1^2 . \frac{\pi^2}{nl\nu} . \sin\left(\frac{1}{2}\pi . \frac{y}{l}\right)}; \end{aligned}\right\} \tag{29}$$

$$\frac{I}{\nu} . \frac{d^2\varphi}{dt^2} = \frac{\pi^2 . k_1^2}{\nu . n . l . g} . \sin\left(\frac{1}{2}\pi . \frac{y}{l}\right) . \frac{p_1 . g . \pi . \nu^2 . + W . V^2 . \frac{\pi}{2l} . \cot\left(\frac{1}{2}\pi . \frac{y}{l}\right)}{1 + A . k_1^2 \frac{\pi^2}{n . l . \nu} . \sin\left(\frac{1}{2}\pi . \frac{y}{l}\right)}; \tag{30}$$

$$C = p_1 . 2\nu . (y + c). \tag{31}$$

At the mouth of the gun $y = l$, and the working formulas for an increasing twist become

$$A = \frac{f + \nu . \frac{\pi^2}{nl}}{1 - f . \nu . \frac{\pi^2}{nl}}; \tag{32}$$

$$P - M \cdot \frac{d^2 y}{dt^2} = A \cdot \frac{\pi^2 k_1^2}{n.\,l} \cdot \frac{p_1 . \pi . \nu}{1 + A \cdot \frac{\pi^2 k_1^2}{n.\,\nu.\,l}}; \tag{33}$$

$$\frac{I}{\nu} \cdot \frac{d^2 \Psi}{dt^2} = \frac{\pi^2 k_1^2}{n.\,l} \cdot \frac{p_1 . \pi . \nu}{1 + A \cdot \frac{\pi^2 . k_1^2}{n.\,\nu.\,l}}; \tag{34}$$

$$C = 2 p_1 . \nu \,(l + c). \tag{35}$$

RADIUS OF GYRATION.

Lieut. Lawrence L. Bruff, Ordnance Department, found the radius of gyration of a 700-pound Butler projectile as follows:

The projectile was suspended from an axis passing through its body near the periphery and parallel to its axis of rotation. The data were

Length between axes, $\epsilon = 3''.96875$.
Latitude of Rock Island Arsenal $= 41^\circ\, 31'\, 22''.8 = \Psi$.
Number of vibrations of projectile per minute $= 131$.
1st. $g = 32.170859$ feet.
2d. Simple seconds pendulum $l^1 = 3.259573$ feet.
3d. Equivalent simple pendulum $= l$.

$$l = \frac{l^1\,(3600)^2}{N^2} = \frac{3.259573 \times \overline{3600}^2}{\overline{7860}^2}$$

(*Bartlett's Mechanics*, pp. 257, 258.)

$$l = .68378 \text{ feet} = 8.20536 \text{ inches}.$$

4th. To find $k_1$ in reference to axis through center,

$$Mk_1^2 = Mle - Me^2, \text{ or } k_1^2 = le - e^2$$
$$k_1^2 = 16.81405,\ k_1 = 4.1005358 \text{ inches}.$$

The Butler projectile, consisting of a cylindrical body with an ogival head, has a core which is also a cylinder terminated at both ends ogivally by heads struck with different radii. Even if the form and variation in weight of the brass sabot be left out of the question, the body is not continuous throughout, and it would be difficult, if not impossible, to find a reliable radius of gyration by any operation of the calculus. For all practical purposes this factor for similar Butler projectiles may be found by making their masses proportional to the cubes of their radii of gyration.

## PART II.

### MATERIALS AMD DIMENSIONS OF GUNS.

(1.) It has been shown that the principle of *rifling* is, of itself, no sufficient cause of the disasters which have characterized some of our artillery practice,* and that if these disasters did not wholly arise from sheer carelessness, as many doubtless did, the source of trouble must be sought outside of the mere fact of rifling.

* Professor Bartlett refers to the large number of Parrott guns that burst during the late war, especially at the siege of Charleston. On Morris Island there was no carelessness in working the guns that human watchfulness could prevent. Generals Alfred H. Terry and John W. Turner had immediate charge of the artillery operations, and they

(2.) It does not appear that the propagation of molecular disturbance, by which alone the forces of resistance to the expanding action of gases are developed and brought into action, has ever been duly considered in the choice of the material and adjustment of the dimensions of guns, and yet it is of all considerations the most important.

In the preceding pages an attempt has been made to construct a set of formulas by which to compute the strains upon rifled guns. It is now proposed to indicate the influence which the rate of molecular disturbance has upon the capacity of a gun to resist the more important of these strains called the *circumferential* (tangential).

(3.) It is well known that the velocity of molecular disturbance is in nowise dependent upon the intensity of the initial forces which produce it, but results wholly from peculiarity of molecular structure that determines *elasticity* and *density*. This velocity is always the same in the same body; and a body to preserve its identity, in this connection, must preserve its temperature and the external pressure upon it unchanged. The material of a gun after repeated firing, by which it becomes heated and thrown into a new *set*, is not the same as before the firing began.

(4.) It is by the propagation of molecular disturbance that the forces of resistance are developed and brought into action, and the rate of this propagation is measured by the velocity of sound in the gun material.

(5.) When powder is burned behind a projectile, the first action of the expanding gas is to enlarge the bore and compress the metal in the direction of the radius, and this action may be so intense and sudden as to break up the molecular structure within before the outer portion can come to its support, and tear the gun as an ordinary force would a piece of cloth applied to its edge. This would be the case, for instance, with an active fulminate, in which the limits of stable equilibrium of the chemical forces are very narrow.

(6.) Take the following notation, viz:

$M$ = Modulus of the gun's material.
$p$ = Pressure of the gas on unit of surface.
$\nu$ = Radius of bore.
$c$ = Thickness of gun.
$l$ = Length of bore on which $p$ is exerted.
$V$ = Velocity of sound in gun material.
$t$ = Time since the beginning of the explosion to the instant of greatest action.
$Qr$ = Quantity of work of gun resistance.
$Qp$ = Quantity of work of the expanding gas on gun.

(7.) Take the axis of the gun for the axis of $y$—a line at right angles thereto for that of $x$. The circumference of the bore before firing will be

$$2\pi . \nu;$$

and at any time after the explosion begins,

$$2\pi(\nu + \sigma\nu),$$

were constantly in the batteries, superintending the fire and instructing the men. The bursting of shells within the bore, which often happened, especially when they contained any of the so-called "Greek-fire" humbug, probably assisted in breaking some of these guns. The 30 and 300 pounder Parrots worked admirably; the 100-pounder was a passable emergency gun, while the 200-pounder was justly dreaded by everybody compelled to be near it when it was fired.

in which $\sigma\nu$ is the increase of $\nu$. And the expansion of the circumference will be

$$2\pi(\nu+\sigma\nu)-2\pi\nu=2\pi\,.\,\sigma\nu,$$

and on a unit of length,

$$\frac{2\pi\sigma\nu}{q\pi\nu}=\frac{\sigma\nu}{\nu}.$$

Conceive a circular ring of radius $x$, and of which the plane is perpendicular to the gun's axis, and let the area of a section of this ring, by a plane through the axis, be $dx\,.\,dy$.

When the circumference of the bore is expanded by $2\pi\,.\,\sigma\nu$, that of this ring will be $2\pi\,.\,\sigma x$; and on a unit of length

$$\frac{2\pi\,.\,\sigma x}{2\pi x}=\frac{\sigma x}{x}.$$

By the principles of wave propagation,

$$\frac{\sigma x}{x}=\frac{\sigma\nu}{\nu}\,.\,\sin\left(\frac{1}{2}\pi\frac{Vt+\nu-x}{Vt}\right);^{*} \qquad (1)$$

with the condition that

$$Vt+\nu>x, \qquad (2)$$

without which the disturbance will not move fast enough to develop resistance by the time it is needed.

The molecular resistance on a unit of surface, supposing every element of the unit to exert a resistance equal to that on $dx\,.\,dy$, will be

$$M\,.\,\frac{\sigma x}{x}.$$

And on the elements $dx\,.\,dy$,

$$M\frac{\sigma x}{x}\,.\,dx\,.\,dy.$$

The elementary quantity of work of this resistance, on a unit of length of the ring, will be

$$M\,.\,\frac{\sigma x}{x}\,.\,d\frac{\sigma x}{x}\,.\,dx\,.\,dy.$$

which integrated between the limits $\frac{\sigma x}{x}=o$ and $\frac{\sigma x}{x}=\frac{\sigma x}{x}$, will give the work of resistance in a unit of length of the ring. This integration gives

$$\frac{1}{2}M\left(\frac{\sigma x}{x}\right)^2.\,dx\,.\,dy,$$

* *Bartlett's Acoustics and Optics*, page 58. The quantity $Vt+\nu$ denotes the linear distance of the front of the wave or pulse from the source; $Vt+\nu-x$, the distance of the molecule's place of rest from the wave front.

and in the entire ring

$$2\,\pi x\,.\,\frac{1}{2}\,M\,.\,\frac{\sigma x^2}{x^2}\,.\,dx\,.\,dy = \pi\,.\,M\,.\,\frac{\sigma x^2}{x^2}.\,xdx\,.\,dy.$$

Replacing $\frac{\sigma x}{x}$ by its value in the wave function (1), and indicating the integration within the limits of $l$ and $c$, we get

$$Qr = \int_{y=l}^{y=o}\int_{x=\nu+c}^{x=\nu} \pi\,.\,M\,.\,\frac{\sigma\nu^2}{\nu^2}\,dy\,\sin^2\left(\frac{1}{2}\pi\frac{Vt+\nu-x}{Vt}\right)xdx,$$

or $$\left.\begin{array}{l} Qr = \text{or}\ \pi\,.\,M\,.\,\frac{\sigma\nu^2}{\nu^2}\,.\,l\,.\left[\frac{1}{4}(\nu+c)^2-\frac{1}{4}\nu^2+\frac{1}{2}\nu+c)\,.\,\frac{Vt}{\pi}\,.\right. \\ \left.\sin\left(\pi\,.\,\frac{c}{Vt}\right)-\left(\frac{Vt}{\pi}\right)\,.\,\sin^2\left(\frac{1}{2}\pi\frac{c}{Vt}\right)\right] \end{array}\right\} \quad (3)$$

(8.) In the incipient state of powder inflammation the gas pressure is zero, and this pressure reaches a maximum when the bore is most enlarged. Denoting by $p$ the varying value of the pressure upon a unit of surface; by P its maximum value; and by $(\sigma\nu)$ the varying value of $\sigma\nu$, we may write

$$p = P\,.\,\sin\left(\frac{1}{2}\pi\,.\,\frac{(\sigma\nu)}{\sigma\nu}\right).$$

The pressure upon the interior surface of which the length is $l$ is

$$2\,\pi\,.\,\nu\,.\,l\,.\,p = 2\,\pi\,.\,\nu\,.\,l\,.\,P.\sin\left(\frac{1}{2}\pi\frac{(\sigma\nu)}{\sigma\nu}\right),$$

and the work of this pressure from the beginning till the bore has its greatest expansion is

$$Qp = \int_{(\sigma\nu)=\sigma\nu}^{(\sigma\nu)=o} 2\,\pi\,.\,\nu\,.\,l\,.\,P\,.\,\sin\left(\frac{1}{2}\pi\frac{(\sigma\nu)}{\sigma\nu}\right)d\,(\sigma\nu) = 4.\,\nu\,.\,\sigma\nu\,.\,l\,.\,P.$$

But $Qr$ and $Qp$ must be equal. Hence, after omitting the common factors and multiplying by $\nu$, we have

$$\left.\begin{array}{l} M\,.\,\frac{\sigma\nu}{\nu}\left[\frac{1}{4}(\nu+c)^2-\frac{1}{4}\nu^2+\frac{1}{2}(\nu+c)\,.\,\frac{Vt}{\pi}\,.\,\sin\left(\pi\,.\,\frac{c}{Vt}\right)-\right. \\ \left.\left(\frac{Vt}{\pi}\right)^2.\,\sin^2\left(\frac{1}{2}\pi\,.\,\frac{c}{Vt}\right)\right]=\frac{4}{\pi}\nu^2.\,P. \end{array}\right\} \quad (4)$$

(9.) Make $\varphi =$ the variable ratio of the sine to its arc; that is,

$$\varphi = \frac{\sin\left(\pi\,\frac{c}{Vt}\right)}{\pi\,.\,\frac{c}{Vt}}; \quad (5)$$

$$\varphi_1^2 = \frac{\sin^2\left(\frac{1}{2}\pi \cdot \frac{c}{Vt}\right)}{\left(\frac{1}{2}\pi \cdot \frac{c}{Vt}\right)^2}; \tag{6}$$

and we have

$$M \cdot \frac{\sigma\nu}{\nu^2}\left[\frac{1}{4}(\nu + c)^2 - \frac{1}{4}\nu^2 + \frac{1}{2}(\nu + c)\,c \cdot \varphi - \frac{1}{4}\varphi_1^2 c^2\right] = \frac{4}{\pi} \cdot \nu \cdot P. \tag{7}$$

(10.) The least possible value for $\varphi$ is zero, and this will occur when

$$\frac{c}{\ } = 1,$$

or when the molecular disturbance only reaches the outer surface of the gun at the instant of greatest action on the bore, in which case the outer layer of molecules will afford no aid whatever.

If

$$\frac{c}{Vt} > 1,$$

then the disturbance would fall short of the outer surface at the instant of greatest action, and all that part of the gun beyond the wave front would be useless.

(11.) The greatest value for $\varphi$ is unity, and this will happen when the arc is so small that the sine may be taken equal to the arc; that is, when the molecular disturbance moves with great rapidity and the powder burns very slowly.

(12.) The velocity of sound through cast-iron is about 18673 feet a second; and it is stated in *Benton's Ordnance and Gunnery*, page 48, that a grain of powder of a particular kind, and having a diameter of 0.056 inch, will burn up in 0.056 of a second. Making, therefore,

$$V = 18673^{f}$$
$$t = 0.056^{s}$$

we find

$$Vt = 1045^{f}.7$$
$$\frac{\pi}{Vt} = 0.003.$$

(13.) So that in ordinary practice $\varphi$ and $\varphi_1$ may be taken as equal to unity, and equation (7) becomes

$$M \cdot \frac{\sigma\nu}{\nu_\cdot}\,[c^2 + 2\,c\,\nu] - \frac{8}{\pi} \cdot P \cdot \nu^2{}_1 \tag{8}$$

or

$$M \cdot \frac{\sigma\nu}{\nu} = \frac{8}{\pi} \cdot \frac{P \cdot \nu^2}{c^2 + 2\,c\,\nu}. \tag{9}$$

The first member is the tensile strain upon a unit of surface of a section through the axis, each element of the surface having the same strain and equal to that on a cross-section of the circular filament in the surface of the bore.

(14.) Solving with respect to P,

$$P = \frac{\pi}{8} \cdot M \cdot \frac{\sigma\nu}{\nu} \cdot \frac{c\,(c + 2\,\nu)}{\nu^2}, \tag{10}$$

which gives the internal pressure just sufficient to produce the tensile strain $M \cdot \frac{\sigma\nu}{\nu}$.

(15.) Solving with respect to $\sigma\nu$, we have

$$\sigma\nu = \frac{8}{\pi} \cdot \frac{P}{M} \cdot \frac{\nu^3}{c^2 + 2\,\nu\,c}, \tag{11}$$

which gives the enlargement of the bore.

(16.) Dividing both members of equation (9) by P there will result,

$$\frac{M \cdot \frac{\sigma\nu}{\nu}}{P} = \frac{8}{\pi} \cdot \frac{\nu^2}{c^2 + 2\,\nu\,c}, \tag{12}$$

which gives a direct relation between the tension of the gas, as measured by its pressure on unit of surface of the bore, and the tensile strain upon the material of the gun on an equal extent of section through the axis. This for the same gun is constant.

(17.) Solving equation (9) with respect to $c$, we find

$$c = -\,\nu \left( 1 \mp \sqrt{1 + \frac{8}{\pi} \cdot \frac{P}{M \cdot \frac{\sigma\nu}{\nu}}} \right) \tag{13}$$

This will give the thickness necessary to resist the pressure P, which develops the tensile strain $M \frac{\sigma\nu}{\nu}$, the radius of the bore being $\nu$, and the upper sign being taken to satisfy the inequality (2).

(18.) On the other hand, if the powder be excessively quick, $Vt$ would become comparatively small. Let us, for illustration, suppose it equal to $c$, which would bring the wave front only to the outer surface of the gun when the gas has its greatest action; then would

$$\varphi = 0, \text{ and } \varphi_1^2 = \frac{4}{\pi^2},$$

and equation (7) would become, writing $c_1$ for $c$,

$$M \cdot \frac{\sigma\nu}{\nu} \cdot \left[ \frac{1}{4} (\nu + c_1)^2 - \frac{1}{4} \nu^2 - \frac{1}{\pi^2} \cdot c_1^2 \right] = \frac{4}{\pi} \cdot P \cdot \nu^2,$$

or

$$M \cdot \frac{\sigma\nu}{\nu} \cdot \left[ \frac{\pi^2 - 4}{4\,\pi^2} \cdot c_1^2 + \frac{1}{2} \nu\, c_1 \right] = \frac{4}{\pi} \cdot P \cdot \nu^2,$$

and solving with respect to $c_1$,

$$c_1 = -\frac{\pi^2}{\pi^2-4} \cdot \nu . \left[ 1 \pm \sqrt{1 + 16 \frac{\pi^2-4}{\pi^3} \cdot \frac{P}{M \cdot \frac{\sigma\nu}{\nu}}} \right] \tag{14}$$

which is much greater than the value for $c$ as given by equation (13), and which shows that a gun having its dimensions properly adjusted to slow powder might fail under the action of one much quicker. Indeed, there can be no doubt that many good guns have been broken by the use of powder rendered unfit for cannon practice by its superior quickness. Quick powder gives no better range, often crushes the projectile in shell firing, and unnecessarily taxes, if it does not destroy, the gun. Its use should be avoided.

The velocity of molecular disturbance increases with an increase of elasticity and diminution of density. Gun metal should, therefore, possess the *greatest elasticity* and *least density* consistent with high tenacity.

(19.) In the report of the Constructor of Ordnance on the casting of the 12.25-inch muzzle-loading rifle at the South Boston Foundry, May 30, 1877, the tenacity of the Dover & Muirkirk* gun-iron is given at 33,881 pounds for a radial specimen taken from outside of gun at about 19 inches from muzzle.

This is the value of $M\frac{\sigma\nu}{\nu}$ at the breaking point for this quality of iron. Taking the case of the 12.25-inch rifle, we shall have

$$M\frac{\sigma\nu}{\nu} = 33881 \text{ pounds},$$
$$\nu = 0^{f}.509875$$
$$c = 1^{f}.78125,\dagger$$

which in equation (10) give

$$P = 255382 \text{ pounds}$$

for the pressure on a square inch of bore, which would be sufficient to break a gun made of the Dover & Muirkirk iron and having the dimensions of the 12.25-inch rifle.

(20.) In the report of the United States Ordnance Board‡ on the trial of the 12.25-inch rifle, it appears that this gun was fired March 15, 1878, with a charge of 115 pounds of Dupont's hexagonal powder and a Butler projectile of 700 pounds, giving a pressure of 33,500 pounds per square inch of bore. Hence making

$$P = 33500 \text{ pounds},$$
$$\nu = 0^{f}.509875$$
$$c = 1^{f}.78125$$

and substituting in equation (9), we have

$$M\frac{\sigma\nu}{\nu} = 4444 \text{ pounds}$$

for the tensile strain on a square inch.

* Equal quantities of Dover & Muirkirk were used in charging the furnaces.

† Calculated for the entire thickness of the gun as though it were all cast-iron. The wrought-iron tube still further strengthens it and enables it to bear a greater strain.

‡ Report of the Chief of Ordnance, 1878, page 437.

(21.) From the report of the Constructor of Ordnance* concerning the casting of the 12-inch rifle at South Boston Iron Foundry, March 19, 1877, it appears that the average elastic limits of the specimens of mixed Dover & Muirkirk iron were for a strain of extension 9,500 pounds, and for a strain of compression 8,250 pounds. The average extension and compression per inch corresponding to these figures were 0.00051125 and 0.00099 inches.

The moduli, computed from these data, are for the extension,

$$M = 18581900;$$

and for the compression,

$$M = 8333333.$$

Every variation in the modulus requires a corresponding variation in the value of $c$, equation (13). And that a gun may be uninjured by firing, the value of $M \frac{\sigma\nu}{\nu}$ should never exceed the maximum tension, or compression, from which the gun may recover its dimensions and keep its molecular structure unaltered. This, in the present case, is 8,250 pounds, and which in equation (10) will give, in the case of any gun made of this iron, and whose radius and thickness are respectively $\nu$ and $c$, the maximum gas pressure to which such gun should be exposed. This prescribes a rule for the treatment of guns in actual service.

(22.) If the exigencies of an occasion require a greater pressure, then the gun, after a certain number of rounds, should be thrown aside, broken up, and recast.

(23.) But if it be the question to construct a gun to bear a given gas pressure, and of which the material will bear the tensile strain $M \frac{\sigma\nu}{\nu}$ without change of molecular structure, we have only to substitute the given pressure P and the tensile strain in equation (13) to find the necessary thickness.

It is quite apparent that all guns have their limits of endurance, and that these limits are somewhat narrow. Those charged with their use have ever at hand the means of pushing them beyond these limits, and these means they are very apt to apply unless restrained by well-defined and very positive rules. These rules require a knowledge of the relations which connect the proportions of the constituents of powder, density, size of grain and volume, with the pressure which the gas arising from its combustion exerts upon the bore of the gun.†

(24.) It is of importance to gun practice that the pressures of gas arising from the burning of different kinds of powder be accurately ascertained, and a series of experiments, free from all objections and having for its object to supply this information, is desirable.

* Report of the Chief of Ordnance, 1877, pages 673 to 680, inclusive.

† Professor Bartlett then states that we do not possess this knowledge, and refers to his objections, founded upon the principles of mechanics, to Major Rodman's inferences from his plug experiments. In support of these objections he gives a table showing the results of a series of experiments by Mr. Parrott with one of his 100-pounders, and says it is sufficient simply to run the eye over the last two columns and note the almost entire absence of correspondence between the plug indications and the ranges to be satisfied of the little reliance to be placed upon the former. To determine the gas pressure he takes a block of copper, neither hammered nor rolled, and

(25.) To find the greatest gas pressure to which a gun of given dimensions should be subjected without impairing its quality of endurance it

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presses the cutter to it by a dead weight without velocity, so that the resistance of the copper may measure the weight. He assumes as the law which connects the resistance with the penetration

$$W = Ax^m$$

in which $m$ is a constant as well as A; both to be found by experiment, and deduces the following equation:

$$A = \frac{(2 \tan \frac{1}{2} Q)^m . W}{y\, m}. \tag{1}$$

in which

$W$ = Weight equal to copper resistance.
$x$ = Depth of penetration of cutter.
$y$ = Length of cut.
$Q$ = Angle of cutter.
$A$ = Copper resistance for unit of penetration.

By repeated trials with different weights, but with the same cutter and copper, a series of values for $m$ and A may be found, and these being treated by the principle of least squares will give the most probable values for the constants $m$ and A.

The copper should not be beaten or rolled, but simply cast and planed to a smooth surfase with a very sharp tool.

He finds the value of $m$ from this expression:

$$m = \frac{\text{Log } W_1 - \text{Log } W}{\text{Log } y_1 - \text{Log } y} \tag{2}$$

in which $y_1$ is the length of cut corresponding to the weight $W_1$.

To supply these preliminaries to the finding of gas pressures he observes that when the powder begins to burn the pressure is nothing, and at the close of the action it is also nothing; that is, the initial and terminal values of the pressure are zero, having a maximum value somewhere between. He gives, as the simplest law of continuity which connects these varying values together, the expression:

$$p = P . \sin\left(\pi . \frac{x}{l}\right)$$

in which $p$ denotes the pressure, in pounds, upon the plug-head, P the maximum pressure upon the same, and $l$ the greatest value for $x$, or the entire penetration. Denoting by $a$ the maximum value of $y$, or the entire length of the cut, answering to $l$ he finds from his previous analysis

$$l = \frac{a}{2 \tan \frac{1}{2} Q},$$

and finally

$$P = \frac{\pi}{2\,(m+1)} . A . \left(\frac{a}{2 \tan \frac{1}{2} Q}\right)^m .$$

A and $m$ are known, equations (1 and 2); $a$ may be measured by the Filar micrometer with great accuracy, whence P becomes known. The value of P, multiplied by the ratio of the area unity to that of the plug-head, gives the pressure on unit of surface, or P in equation (7).

He objects to the form of Rodman's cutter, and states it would be much better to use a conical point, and rely upon a Filar micrometer, with great magnifying power in the eye-glass, to measure the surface diameter of the penetration.

The theory of Professor Bartlett has been adopted by Lieut. Henry Metcalfe, Ordnance Department, in the construction of the spiral pressure gauge. In the report of the Chief of Ordnance, for 1877, Lieutenant Metcalfe says: "In this connection, the remark of Professor Bartlett in his pamphlet on strains on rifle guns, page 31, occurred to me, viz, that the form of the Rodman cutter seemed objectionable, and that it would be better to use a conical point, and measure the surface-diameter of its penetration by a Filar micrometer of high magnifying power. I thought that, by devising some plan of readily measuring the penetration of this conical point, the compactness of the one plan might be combined with the simplicity of the other."

will be only necessary, as previously stated, to substitute in equation (10) for M $\frac{\sigma\nu}{\nu}$ the greatest strain (of extension or compression) from which the material may recover its former figure after being relieved. In the case of the Dover & Muirkirk iron this is 8,250 pounds, and for the 12.25-inch rifle we find

$$P = 62000 \text{ pounds.}$$

(26.) Again, let it be required to find the thickness of a 12.25-inch rifle to be subjected to a gas pressure double this, and yet the strain (of extension or compression) from which the material may recover its former figure not to exceed 8,250 pounds. Then equation (13)

$$c = 2^{\prime\prime}.6854,$$

which is the thickness necessary to resist a pressure equal to twice 62000 pounds without incurring a strain (of compression or extension) greater than 8,250 pounds. It is quite apparent how these numbers will vary with the nature of the gun metal. In the testing of a new gun, means should be provided for measuring the *pitch* of the sound with which it responds to a blow from a light hammer on the face of the muzzle after every discharge. Altered tone will indicate altered structure.

# APPENDIX 23.

**RATIONAL AND PRACTICAL BALLISTICS.—NEW METHODS FOR SOLVING PROBLEMS OF FIRE. BY F. SIACCI, CAPTAIN OF ARTILLERY, MEMBER OF THE ITALIAN ACADEMY OF SCIENCES.**

[Translated from the French, and adapted to the English system of weights and measures, by Lieut. Orin B. Mitcham, Ordnance Department, U. S. A.]

WEST POINT, N. Y., *April* 27, 1881.

SIR: I have the honor to transmit herewith translation of the article by Captain Siacci, of the Italian artillery, published in the Revue d'Artillerie for the month of October, 1880. I have changed, as far as practicable, French weights and measures to English units, and have added a ballistic table, which I have calculated from the formulas given in the article.

In view of the high velocities obtained lately from improved guns, I have begun the table with a velocity of 2,200 feet. To secure this result, I have taken the resistance of the air to vary as the square of the velocity above 1,380 feet per second. Professor Bashforth, in his pamphlet on recent experiments in England to determine this resistance, seems to agree with the supposition that it varies according to this law, even beyond 2,200 feet per second. The values of $\rho'$ given in section 6 have not been changed, as I have not been able to obtain the data from which they were calculated.

General Mayevski, in his Treatise on Ballistics, fails to give the details from which each value was obtained, though he gives the results of his own experiments, as well as of the English experiments, as laid down in the section referred to. I have added to the article range tables calculated for the 8-inch (converted) rifle and the 12-inch breech-loading rifle (proposed model).

I am, sir, very respectfully,

O. B. MITCHAM,
*Lieutenant of Ordnance.*

The CHIEF OF ORDNANCE, U. S. ARMY,
*Washington, D. C.*

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## RATIONAL AND PRACTICAL BALLISTICS.

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### SECTION 3.

To deduce the scientific base of the ballistic table, let

$a$ = the diameter of the projectile,
$p$ = the weight of the projectile,
$v$ = the velocity.

The resistance of the air, if it be supposed directly opposed to the movement and referred to the unit of mass, can be represented gen-

erally by $\frac{a^2}{p}F(v)$, $F(v)$ being a function that increases with the velocity. The differential equations of the motion can be reduced to

$$\left.\begin{aligned} g\,d\,(v\cos\theta) &= \frac{a^2}{p}\,v\,F(v)\,d\,\theta, \\ g\,d\,x &= -\,v^2\,d\,\theta, \\ dt &= \frac{d\,x}{v\cos\theta}, \end{aligned}\right\} \tag{1}$$

in which $g$ is the intensity of the force of gravity, $t$ the time of flight, $x$ the horizontal distance of any point of the trajectory, and $\theta$ the inclination of the tangent at this point. These equations not being in general capable of integration, to make them so recourse is had usually to an alteration in the expression for the resistance; for $F(v)$ there is substituted $\frac{F(a\,v\cos\theta)}{a\cos\theta}$, $a$ being a constant to which is given the mean value that the $\sec\theta$ has in the arc of the trajectory under consideration. The error committed is small when the fire is not very curved.

This being established, let us place $a v\cos\theta = u$. The two first equations reduce to

$$\frac{a^2}{p}\,a\,dx = -\frac{u\,du}{F(u)}. \tag{2}$$

$$\frac{a^2}{pa}\,\frac{d\theta}{\cos^2\theta} = \frac{g\,du}{u\,F(u)}; \tag{3}$$

if we place

$$\left.\begin{aligned} -\int\frac{u\,du}{F(u)} &= D\,(u), \\ -\int\frac{g\,du}{u\,F(u)} &= \tfrac{1}{2}\,I\,(u), \end{aligned}\right\} \tag{4}$$

there is obtained by integration

$$\frac{a^2}{p}\,a\,x = D\,(u) - D\,(U); \tag{5}$$

$$\frac{2a^2}{pa}(\tan\theta - \tan\varphi) = -\,I\,(u) - I\,(U), \tag{6}$$

$\varphi$ being the angle of projection, V the initial velocity, and $U = a\,V\cos\varphi$.

From equation (6)

$$\frac{2a^2}{pa}\left(\frac{dy}{dx} - \tan\varphi\right) - I\,(U) = I\,(u);$$

multiplying this member by member with equation (2) we get

$$\frac{2a^4}{p^2}\,(dy - dx\tan\varphi) - \frac{a^2}{p}\,I\,(U)\,a\,dx = \frac{I\,(u)}{F\,(u)}\,u\,du,$$

and by integration

$$\frac{2a^4}{p^2}(y - x \operatorname{tang} \varphi) - \frac{a^2}{p} \mathrm{I}(\mathrm{U})\, a\, x = -\mathrm{A}(u) + \mathrm{A}(\mathrm{U}); \tag{7}$$

having placed, in order to shorten the work,

$$-\int \frac{\mathrm{I}(u)}{\mathrm{F}(u)} u\, du = \mathrm{A}(u). \tag{8}$$

Dividing equation (7) by equation (5) we have

$$\frac{2a^2}{pa}\left(\frac{y}{x} - \operatorname{tang} \varphi\right) - \mathrm{I}(\mathrm{U}) = -\frac{\mathrm{A}(u) - \mathrm{A}(\mathrm{U})}{\mathrm{D}(u) - \mathrm{D}(\mathrm{U})}. \tag{9}$$

For the time of flight the third of equations (1) gives:

$$\frac{a^2}{p} dt = \frac{a^2}{p} \frac{a\, dx}{u};$$

by eliminating $a\, dx$ by means of equation (2),

$$\frac{a^2}{p} dt = -\frac{du}{\mathrm{F}(u)},$$

and by integration

$$\frac{a^2}{p} t = \mathrm{T}(u) - \mathrm{T}(\mathrm{U}), \tag{10}$$

if we place

$$-\int \frac{du}{\mathrm{F}(u)} = \mathrm{T}(u). \tag{11}$$

Summing up, then, we have

$$x = \frac{p}{a^2 a}\Big[\mathrm{D}(u) - \mathrm{D}(a \mathrm{V} \cos \varphi)\Big]. \tag{12}$$

$$\operatorname{tang} \theta = \operatorname{tang} \varphi - \frac{pa}{2a^2}\Big[\mathrm{I}(u) - \mathrm{I}(a \mathrm{V} \cos \varphi)\Big]. \tag{13}$$

$$\frac{y}{x} = \operatorname{tang} \varphi - \frac{pa}{2a^2}\left[\frac{\mathrm{A}(u) - \mathrm{A}(a \mathrm{V} \cos \varphi)}{\mathrm{D}(u) - \mathrm{D}(a \mathrm{V} \cos \varphi)} - \mathrm{I}(a \mathrm{V} \cos \varphi)\right]. \tag{14}$$

$$t = \frac{p}{a^2}\Big[\mathrm{T}(u) - \mathrm{T}(a \mathrm{V} \cos \varphi)\Big]. \tag{15}$$

## SECTION 4.

LEMMA.—By means of a lemma easily admissible, we can render independent of $a$ the last equations, which give the velocity, the inclination, the ordinate, and the time of flight for the distance $x$.

If equation (12) be solved with reference to $u$, it can be put under the form:

$$u = a\, v \cos \theta = a \mathrm{V} \cos \varphi\, \Phi(a\, x, a \mathrm{V} \cos \varphi), \tag{16}$$

$\Phi$ being a function that reduces to unity, when the resistance becomes zero. If the value of $u$ given by equation (16) be substituted in equations (13), (14), and (15), and if it be noticed that the three functions

$$\left[\mathrm{I}(u) - \mathrm{I}(a\,\mathrm{V}\cos\varphi)\right] \quad \left[\frac{\mathrm{A}(u) - \mathrm{A}(a\,\mathrm{V}\cos\varphi)}{\mathrm{D}(u) - \mathrm{D}(a\,\mathrm{V}\cos\varphi)} - \mathrm{I}(a\,\mathrm{V}\cos\varphi)\right],$$

and

$$\left[\mathrm{T}(u) - \mathrm{T}(a\,\mathrm{V}\cos\varphi)\right]$$

are functions of $a\,x$ and $a\,\mathrm{V}\cos\varphi$, equations (13), (14), and (15) can be put under the form:

$$\operatorname{tang}\theta = \operatorname{tang}\varphi - a\left(\frac{g\,a\,x}{a^2\,\mathrm{V}^2\cos^2\varphi}\right)\Phi_1(a\,x, a\,\mathrm{V}\cos\varphi),$$

$$\frac{y}{x} = \operatorname{tang}\varphi - a\left(\frac{g\,a\,x}{2\,a^2\,\mathrm{V}^2\cos^2\varphi}\right)\Phi_2(a\,x, a\,\mathrm{V}\cos\varphi),$$

$$t = \frac{a\,x}{a\,\mathrm{V}\cos\varphi}\Phi_3(a\,x, a\,\mathrm{V}\cos\varphi).$$

Or,

$$\left\{\begin{aligned} &\operatorname{tang}\theta = \operatorname{tang}\varphi - \frac{g\,x}{\mathrm{V}^2\cos^2\varphi}\Phi_1(a\,x, a\,\mathrm{V}\cos\varphi),\\ &\frac{y}{x} = \operatorname{tang}\varphi - \frac{g\,x}{2\,\mathrm{V}^2\cos^2\varphi}\Phi_2(a\,x, a\,\mathrm{V}\cos\varphi),\\ &t = \frac{x}{\mathrm{V}\cos\varphi}\Phi_3(a\,x, a\,\mathrm{V}\cos\varphi),\end{aligned}\right. \tag{17}$$

$\Phi_1$, $\Phi_2$, $\Phi_3$ reducing to unity when the resistance becomes zero. The lemma already mentioned is as follows: *The functions* $\Phi$, $\Phi_1$, $\Phi_2$, $\Phi_3$ *undergo no appreciable variation when* $x$ *is replaced by* $\frac{x}{a}$, *and at the same time* V *by* $\frac{\mathrm{V}}{a\cos\varphi}$. It will be seen that the values of these functions must vary from the values that they have *in vacuo*—that is, they must increase beyond unity in proportion to the increase in the distance and initial velocity; now, by putting $\frac{x}{a}$ for $x$ and $\frac{\mathrm{V}}{a\cos\varphi}$ for V, on the one hand the distance is diminished a little; on the other hand, the initial velocity is increased a little, since $a$ is generally comprised between 1 and sec $\varphi$.

The two partial variations that these substitutions make the functions $\Phi$, $\Phi_1$, $\Phi_2$, $\Phi_3$ undergo are then with a contrary sign, and it can be admitted in practice that the resulting variation is almost nothing.

This conclusion will be the more readily received if we consider the values that the four functions $\Phi$, $\Phi_1$, $\Phi_2$, $\Phi_3$ take in the general case, where the resistance of the air is proportional to a power of the velocity; as, for instance,

$$\frac{a^2}{p}\mathrm{F}(v) = \mathrm{C}\,v^n.$$

We have, then,*

$$\Phi = \frac{1}{[1+(n-2)\,C\,(\alpha\,V\cos\varphi)^{n-2}\,\alpha\,x]^{\frac{1}{n-2}}},$$

$$\Phi_1 = \frac{1}{n\,C\,(\alpha\,V\cos\varphi)^{n-2}\,\alpha\,x}\left\{\left[1+(n-2)\,C\,(\alpha\,V\cos\varphi)^{n-2}\,\alpha\,x\right]^{\frac{n}{n-2}}-1\right\},$$

$$\Phi_2 = \frac{1}{n(n-1)\,C^2(\alpha\,V\cos\varphi)^{2n-4}\alpha^2x^2}\left\{\left[1+(n-2)\,C\,(\alpha\,V\cos\varphi)^{n-2}\,\alpha\,x\right]^{\frac{2n-2}{n-2}}\right.$$
$$\left.-\left[1+2(n-1)\,C\,(\alpha\,V\cos\varphi)^{n-2}\,\alpha\,x\right]\right\},$$

$$\Phi_3 = \frac{1}{(n-1)\,C\,(\alpha\,V\cos\varphi)^{n-2}\,\alpha\,x}\left\{\left[1+(n-2)\,C\,(\alpha\,V\cos\varphi)^{n-2}\,\alpha\,x\right]^{\frac{n-1}{n-2}}-1\right]\right\}.$$

If now, in these expressions, $\frac{x}{\alpha}$ and $\frac{V}{\alpha\cos\varphi}$ be put in the place of $x$ and V, respectively, we obtain

$$\psi = \frac{1}{[1+(n-2)\,C\,V^{n-2}\,x]^{\frac{1}{n-2}}},$$

$$\Phi_1 = \frac{1}{n\,C\,V^{n-2}\,x}\left\{\left[1+(n-2)\,C\,V^{n-2}\,x\right]^{\frac{n}{n-2}}-1\right\},$$

$$\Phi_2 = \frac{1}{n(n-1)\,C^2\,V^{n-4}}\left\{\left[1+(n-2)\,C\,V^{n-2}\,x\right]^{\frac{2n-2}{n-2}}\right.$$
$$\left.-\left[1+2(n-1)\,C\,V^{n-2}\,x\right]\right\},$$

$$\Phi_3 = \frac{1}{(n-1)\,C\,V^{n-2}\,x}\left\{\left[1+(n-2)\,C\,V^{n-2}\,x\right]^{\frac{n-1}{n-2}}-1\right]\right\}.$$

But the same expressions would have been obtained if, without changing $x$ and V, we had placed $\alpha^{n-1}(\cos\varphi)^{n-2}=1$; then, the substitution of the four new expressions for the old ones is equivalent to supposing that $\alpha=\sqrt[n-1]{(\sec\varphi)^{n-2}}$, and this value of $\alpha$ is comprised between 1 and $\sec\varphi$, if $n>2$. This being supposed, we can consider, practically, that

$$\Phi\,(\alpha\,x,\,\alpha\,V\cos\varphi)=\Phi\,(x,\,V),$$
$$\Phi_1(\alpha\,x,\,\alpha\,V\cos\varphi)=\Phi_1(x,\,V),$$
$$\Phi_2(\alpha\,x,\,\alpha\,V\cos\varphi)=\Phi_2(x,\,V),$$
$$\Phi_3(\alpha\,x,\,\alpha\,V\cos\varphi)=\Phi_3(x,\,V).$$

* Siacci, Balistica, vol. i, p. 79.

SECTION 5.

Let it be supposed that a table of the functions D $(u)$, I $(u)$, A $(u)$, T $(u)$ has been calculated for all the values of $u$, and that we wish to know the velocity $v$, the inclination $\theta$, the ordinate $y$, and the time $t$, for the distance $x$; the initial velocity V and angle of projection $\varphi$ are given. It will be necessary to give to $a$ a suitable value and to calculate $U = a V \cos \varphi$; then, to look for D (U) in the table, to add to it $a\,x \frac{a^2}{p}$, and to find in the table the value of $u$ that satisfies the equation

$$D\,(u) = D\,(U) + a\,x \frac{a^2}{p}. \tag{18}$$

Knowing $u$, equations (13), (14), and (15) will give the inclination, the ordinate, and the time; the velocity $v$ will be given by

$$v = \frac{u}{a \cos \theta}.$$

Let us, however, pursue a different method. Instead of placing $U = a V \cos \varphi$, let us place $U = V$, and instead of determining $u$ by equation (18) let us determine it by this equation:

$$D\,(u) = D\,(V) + x \frac{a^2}{p}.$$

We can then calculate tang $\theta$, $\frac{y}{x}$, $t$, and $v$ by the expressions:

$$\text{tang}\,\varphi - \frac{pa}{2\,a^2}\Big[I\,(u) - I\,(V)\Big],$$

$$\text{tang}\,\varphi - \frac{pa}{2\,a^2}\Big[\frac{A\,(u) - A\,(V)}{D\,(u) - D\,(V)} - I\,(V)\Big],$$

$$\frac{p}{a^2}\Big[T\,(u) - T\,(V)\Big],$$

$$\frac{u}{a \cos \theta}.$$

By using this method we would commit an error, and this error would consist in supposing the initial velocity no longer equal to V, but to $\frac{V}{a \cos \varphi}$, and the distance no longer equal to $x$, but to $\frac{x}{a}$.

Instead of the exact quantities that we are seeking, $\theta$, $y$, $t$, and $v$, we would obtain other quantities: $\theta'$, $y'$ $t'$, and $v'$, which, from equations (16) and (17), are given by:

$$\text{tang}\,\theta^1 = \text{tang}\,\varphi - \frac{g\left(\frac{x}{a}\right)}{\left(\frac{V}{a \cos \varphi}\right)^2 \cos^2 \varphi}\,\Phi_1\,(x, V),$$

$$\frac{y^1}{x} = \text{tang } \varphi - \frac{\left(\frac{V}{a \cos \varphi}\right)^2 \cos^2 \varphi}{g\left(\frac{x}{a}\right)} \Phi_2 (x, V),$$

$$t^1 = \frac{\left(\frac{x}{a}\right)}{\frac{V}{a \cos \varphi} \cos \varphi} \Phi_3 (x, V),$$

$$v^1 = \frac{a\left(\frac{V}{a \cos \varphi}\right) \cos \varphi}{a \cos \theta} \Phi (x, V);$$

or,

$$\text{tang } \theta^1 = \text{tang } \varphi - \frac{ag\,x}{V^2} \Phi_1 (x, V),$$

$$\frac{y^1}{x} = \text{tang } \varphi - \frac{a\,g\,x}{V^2} \Phi_2 (x, V),$$

$$t^1 = \frac{x}{V} \Phi_3 (x, V),$$

$$v' = \frac{V}{a \cos \theta} \Phi (x, V).$$

Now, to turn from these erroneous expressions to the true expressions, to formulas (17) and (16), it will suffice to divide by $a \cos^2 \varphi$ the terms that follow tang $\varphi$ in the two first equations and to multiply the values of $t'$ and $V'$ by $\frac{1}{\cos \varphi}$ and $a \cos \varphi$, since, by virtue of the lemma, the four functions $\Phi$, $\Phi_1$, $\Phi_2$, $\Phi_3$ have undergone no change. We have, then,

$$\left\{\begin{aligned} &\text{tang } \theta = \text{tang } \varphi - \frac{p}{2\,a^2 \cos^2 \varphi} \Big[ I\,(u) - I\,(V) \Big] \\ &\frac{y}{x} = \text{tang } \varphi = \frac{p}{2\,a^2 \cos^2 \varphi} \left[ \frac{A\,(u) - A\,(V)}{D\,(u) - D\,(V)} - I\,(V) \right] \\ &t = \frac{p}{a^2 \cos \varphi} \Big[ T\,(u) - T\,(V) \Big] \\ &v = \frac{\cos \varphi}{\cos \theta} u; \end{aligned}\right. \tag{20}$$

$u$ being calculated by the simplified formula

$$D\,(u) = D\,(V) + \frac{a^2}{p} x. \tag{21}$$

If the angle of projection is unknown, while the range X is given, as well as the initial velocity, then we will make $y = o$, and we will obtain

$$(22.)\quad \sin 2\,\varphi = \frac{p}{a^2} \left[ \frac{A\,(u) - A\,(V)}{D\,(u) - D\,(V)} - I\,(V) \right],$$

$u$ being given by formula (21), in which X is put for $x$.

The angle of fall $\omega$ will be equal to $-\theta$; introducing into the first of equations (20) the value of $\varphi$, given by equation (22), we shall have

$$\tan g\ \omega = \frac{\frac{p}{a^2}\Big[\mathrm{I}\ (u) - \mathrm{I}\ (\mathrm{V})\Big] - \sin 2\ \varphi}{2 \cos^2 \varphi};$$

or,

$$(23.)\ \tan g\ \omega = \frac{p}{2\ a^2 \cos^2 \varphi}\left[\mathrm{I}\ (u) - \frac{\mathrm{A}\ (u) - \mathrm{A}\ (\mathrm{V})}{\mathrm{D}\ (u) - \mathrm{D}\ (\mathrm{V})}\right].$$

In practice this formula is inconvenient on account of the denominator $\cos^2 \varphi$; but, by making a slight sacrifice of accuracy, this inconvenience is easily avoided. Multiplying the two members by $2 \cos^2 \omega$, we have

$$\sin 2\ \omega = \frac{\cos 2\ \omega}{\cos 2\ \varphi}\frac{p}{a^2}\left[\mathrm{I}\ (u) - \frac{\mathrm{A}\ (u) - \mathrm{A}\ (\mathrm{U})}{\mathrm{D}\ (u) - \mathrm{D}\ (\mathrm{U})}\right].$$

By replacing the factor $\frac{\cos^2 \omega}{\cos^2 \varphi}$ by unity we have the formula:

$$(24.)\ \sin 2\ \omega = \frac{p}{a^2}\left[\mathrm{I}\ (u) - \frac{\mathrm{A}\ (u) - \mathrm{A}\ (\mathrm{V})}{\mathrm{D}\ (u) - \mathrm{D}\ (\mathrm{V})}\right].$$

This formula is worked as readily as that for $\sin 2\ \varphi$, and gives for $\omega$ a value that exceeds by an insignificant quantity the one that would be obtained by the exact expression. An insignificant error will also be committed by calculating the velocity by the formula:

$$(25.)\ v = u \text{ instead of } v = \frac{u \cos \varphi}{\cos \omega}.$$

In the formulas (21), (22), (23), (24), and (25) we find the demonstration of the rules laid down at the end of this article for the use of the ballistic table. In the latter, however, the functions D $(v)$, I $(v)$, and T $(v)$ have been multiplied by 100, and A $(v)$ by 10,000, to avoid the trouble of using small decimals. It is on this account that there appears in these rules $100\frac{a^2}{p}$ instead of $\frac{a^2}{p}$.

## Section 6.

Having made known the analytical base of the method, the numerical base will now be shown. It is founded on the experiments carried out in Russia and England in 1868 and 1869, on the resistance of the air to the motion of oblong projectiles. In the Russian experiments the velocity of the projectiles at two points of the trajectory, at distances apart varying from 150 meters (492 feet) to 234 meters (768 feet), was measured by two Le Boulongé chronographs. The projectiles were of cast iron with a lead envelope, and of a caliber of 4 pounds, 12 pounds, 24 pounds, and 8 inches. The velocities varied from 172 meters (546 feet) to 409 meters (1,342 feet).

In the English experiments the Bashforth chronograph was used. This allows the velocity to be measured at several points of the same

trajectory. Oblong projectiles of 7, 8, and 9 inches were employed. The velocities varied from 283 meters (928 feet) to 518 meters (1,700 feet.)

Knowing the velocities $v_1$ and $v_2$ at two points of the same trajectory, at a distance $d$ apart, the mean resistance is determined by the formula $\rho = \frac{p}{2\,gd}(v_1{}^2 - v_2{}^2)$, $\frac{p}{g}$ being the mass of the projectile. This resistance can be considered as corresponding to a velocity intermediate between $v_1$ and $v_2$; say to their arithmetical mean $\frac{v_1 + v_2}{2} = v$. The different resistances $\rho$ that correspond to the different velocities, and that are obtained from this formula, can be compared among themselves only so long as the density of the air remains the same and the projectiles are of the same caliber. When the experiments are not carried out under these conditions, the quantity $\rho$ must be referred to a single density and projectile. To obtain this result, supposing that the resistance increases in proportion to the density of the air and the cross-section of the projectile, it would suffice to multiply $\rho$ by the ratio $\frac{1}{\delta\,S}$ ($\delta$ being the weight of a cubic meter of air at the time of the experiment, and S the area of the cross-section of the projectile). But we usually multiply $\rho$ by $\frac{1.206}{\delta\,S\,v^2}$; when the resistances are referred to the case of the air weighing 1.206 kil. per cubic meter, we obtain, by means of the denominator $v^2$, quotients that are less sensible to variations in the velocities.

These quotients would be constant if the resistance varied as the square of the velocity. We have, then, $\rho' = \frac{1.206}{\delta\,S\,v^2}\,\rho$.*

The results of the Russian and English experiments are given in the following table, and are reproduced graphically in the figure where the velocities are taken for abscissas and the values of $\rho'$ for ordinates:

| Kind of gun. | Velocities. $v$. | Values of $\rho'$. | Kind of gun. | Velocities. $v$. | Values of $\rho'$. |
|---|---|---|---|---|---|
| | *Meters.* | | | *Meters.* | |
| Russian 4-pounder | 172 | 0.0151 | Russian 8-inch | 329 | 0.0338 |
| Russian 8-inch | 207 | 0.0137 | English 8-inch | 332 | 0.0327 |
| Russian 4-pounder | 239 | 0.0148 | English 9-inch | 334 | 0.0332 |
| Russian 12-pounder | 247 | 0.0170 | Russian 4-pounder | 337 | 0.0341 |
| Russian 24-pounder | 266 | 0.0160 | English 7-inch | 340 | 0.0334 |
| Russian 8-inch | 282 | 0.0163 | English 8-inch | 345 | 0.0354 |
| English 8-inch | 287 | 0.0184 | English 9-inch | 355 | 0.0364 |
| English 9-inch | 291 | 0.0247 | English 7-inch | 358 | 0.0382 |
| English 8-inch | 300 | 0.0230 | Russian 8-inch | 360 | 0.0384 |
| English 7-inch | 302 | 0.0218 | English 8-inch | 360 | 0.0386 |
| Russian 12-pounder | 304 | 0.0221 | Russian 4-pounder | 401 | 0.0430 |
| Russian 4-pounder | 307 | 0.0158 | Russian 8-inch | 409 | 0.0400 |
| English 9-inch | 316 | 0.0305 | English 8-inch | 419 | 0.0433 |
| Russian 4-pounder | 317 | 0.0259 | English 9-inch | 420 | 0.0437 |
| Russian 8 inch | 319 | 0.0174 | English 8-inch | 460 | 0.0440 |
| English 8-inch | 320 | 0.0277 | English 8-inch | 506 | 0.0446 |
| Russian 24-pounder | 320 | 0.0299 | English 7-inch | 512 | 0.0443 |
| English 7-inch | 322 | 0.0270 | | | |

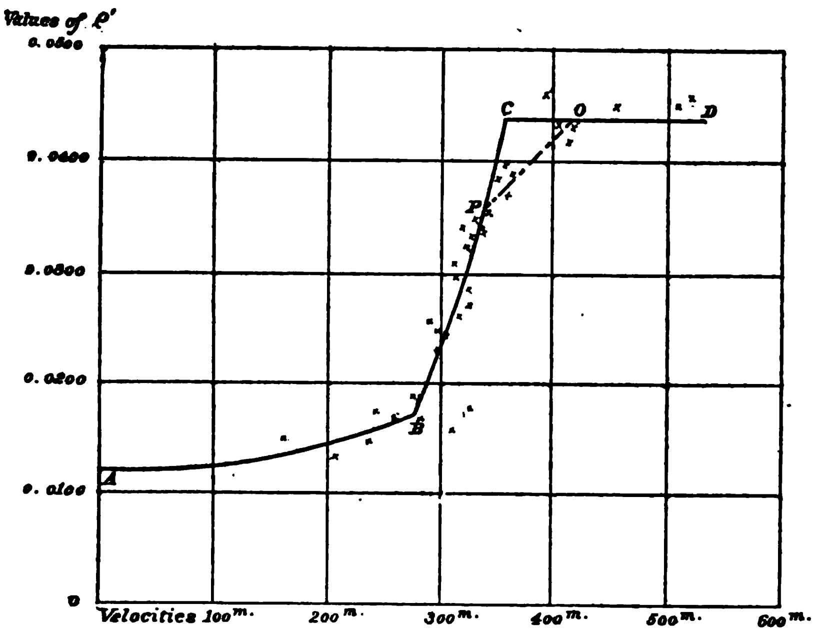
*1.206 kil. is the weight of a cubic meter of air at 15° centigrade (59° Fahrenheit), with a barometric pressure of 29.5 inches, and with the air half saturated with vapor. A cubic foot of dry air at 62° F., and at a pressure of 30 inches mercury, weighs 534.2 grains or 0.0763 pound. This may be taken as a standard to which all the observed resistances can be referred; therefore, $\rho' = \frac{0.0763 \text{ lbs.}}{\delta\,S\,v^2}\rho$, when English units of weight and measure are employed.—*Translator.*

It would not be difficult to find a continuous function that would reproduce with a sufficiently close approximation the results contained in the preceding table. However, it would be difficult to give to this function characters that would render it capable of the integrations indicated in section 3, equations (4), (8), and (11). General Mayevski has adopted a discontinuous function, which is represented geometrically by the broken line A B C D. The three parts of the line have for equations

$\rho' = 0.044$ from 510 meters (1,674 feet) to 360 meters (1,181 feet).

$\rho' = 0.00000000000026v^4$ from 360 meters (1,181 feet) to 280 meters (920 feet).

$\rho' = 0.012\left[1 + \left(\frac{v}{488}\right)^2\right]$ from 280 meters (920 feet) to the lowest velocities.




It has seemed to me that General Mayevski's broken line was susceptible of some improvement. There are in it two angles a little greater than 90°. These indicate changes too abrupt, and consequently too much in contradiction with the continuity proper to natural laws. The discontinuity that is met with, about 280 meters, is not a serious inconvenience; for, at that point, the velocity being small, the value of $\rho = \rho' Sv^2$ does not undergo too great a change for a slight change in $\rho'$. This is not the case with the discontinuity which occurs about 360 meters, and is much more sensible to variations than the first. The great change at this point has not seemed to me justified by experiment, since from 330 meters to 380 meters all the points given, five in number, are on the interior of the angle.

A correction appearing proper, I have cut the angle by the right line P O, which has for its equations $\rho' = 0.00010476\ v$, and which meets the broken line at the points corresponding to the velocities of 343 meters and 420 meters.

In the following table is the comparison, within these limits, between the broken line and the straight line:

| Kind of gun. | Velocities. | Experimental values of | Broken line. | | Straight line. | |
|---|---|---|---|---|---|---|
| | $v$. | $\rho'$. | $\rho'$. | Difference. | $\rho'$. | Difference. |
| | *Meters.* | | | | | |
| English 8-inch | 345 | 0.0354 | 0.0368 | + 0.0014 | 0.0361 | + 0.0007 |
| English 9-inch | 355 | 0.0364 | 0.0413 | + 0.0049 | 0.0372 | + 0.0008 |
| English 7-inch | 358 | 0.0382 | 0.0427 | + 0.0045 | 0.0375 | − 0.0007 |
| Russian 8-inch | 360 | 0.0384 | 0.0437 | + 0.0053 | 0.0377 | − 0.0007 |
| English 8-inch | 360 | 0.0393 | 0.0437 | + 0.0044 | 0.0377 | − 0.0016 |
| Russian 4-pounder | 401 | 0.0450 | 0.0440 | − 0.0010 | 0.0420 | − 0.0030 |
| Russian 8-inch | 409 | 0.0430 | 0.0440 | + 0.0010 | 0.0428 | − 0.0002 |
| English 8-inch | 419 | 0.0433 | 0.0440 | + 0.0007 | 0.0439 | + 0.0006 |

Another slight change has been made. For velocities below 280 meters the formula $\rho' = 0.01206\left(1 + \frac{v^2}{r^2}\right)$, $r = 495.1$, has been adopted in place of that of General Mayevski, $\rho' = 0.01200\left[1 + \frac{v^2}{r^2}\right]$, $r = 488$. The two formulas do not give sensible differences within the limits between which they are to be employed. The value $r = 495.1$, instead of 488, has been taken because this number gives for $\frac{g}{r^2}$ a simple number, 0.00004, which facilitates the numerical calculations that have to be made.

The expressions for the resistance on a unit of mass, all reductions having been made, are:

$\frac{a^2}{p}$ F $(v) = 0.33933 \frac{a^2}{p} v^2$ between $v = 520$ meters (1,706 feet) and $v = 420$ meters (1,378 feet).

$\frac{a^2}{p}(\mathrm{F}(v)) = 0.00080792 \frac{a^2}{p} v^3$ between $v = 420$ meters (1,378 feet) and $v =$ 343 meters (1,125 feet).

$\frac{a^2}{p}$ F $(v) = 0.00000000002 \frac{a^2}{p} v^6$ between $v = 343$ meters (1,125 feet) and $v = 280$ meters (920 feet).

$\frac{a^2}{p}$ F $(v) = 0.093 \frac{a^2}{p} v^2\left[1 + \left(\frac{v}{495.1}\right)^2\right]$ for $v < 280$ meters (920 feet).

NOTE.—If in these equations we write:

$q = 0.33933$; $c = 0.00080792$; $k = 0.00000000002$; $h = 0.093$; $r = 495.1$,

we have, when the formulas are employed with English units of weight and measure,

$q = 0.021184$; $c = 0.000015373$; $k = 0.000000000000010774$; $h = 0.005806$; $r = 1624.4$.

NOTE.—The latter values have been used in calculating the ballistic table given at the end of this article.—*Translator.*

SECTION 7.

It remains to show to what are reduced the functions

$$D(u) = -\int \frac{u\,du}{F(u)};\ I(u) = -\int \frac{2g\,du}{u\,F(u)};$$

$$A(u) = -\int \frac{I(u)}{F(u)}\,u\,du;\ T(u) = -\int \frac{du}{F(u)},$$

when F $(u)$ takes the four forms indicated at the end of the preceding paragraph.

I. VELOCITIES COMPRISED BETWEEN 1,706 FEET AND 1,380 FEET.

$$F(v) = q\,v^2;\ q = 0.021184.$$

$$D(u) = -\frac{1}{q}\int \frac{du}{u} = -\frac{1}{q}\,l(u) + Q.$$

$$I(u) = -\frac{2g}{q}\int \frac{du}{u^3} = \frac{g}{q}\left(\frac{1}{u^2} + Q_1\right).$$

$$A(u) = -\frac{g}{q^2}\int \left(\frac{1}{u^2} + Q_1\right)\frac{du}{u} = \frac{g}{q^2}\left(\frac{1}{2u^2} - Q_1\,l(u) + Q_2\right).$$

$$T(u) = -\frac{1}{q}\int \frac{du}{u^2} = \frac{1}{qu} + Q_3.$$

The quantities $Q$, $Q_1$, $Q_2$, and $Q_3$ are arbitrary constants, and will be determined later.

II. VELOCITIES BETWEEN 1,380 FEET AND 1,120 FEET.

$$F(u) = cu^3;\ c = 0.000015373.$$

$$D(u) = -\frac{1}{c}\int \frac{du}{u^2} = \frac{1}{cu} + C.$$

$$I(u) = -\frac{2g}{c}\int \frac{du}{u^4} = \frac{2g}{3c}\left(\frac{1}{u^3} + C_1\right).$$

$$A(u) = -\frac{2g}{3c^2}\int \left(\frac{1}{u^3} + C_1\right)\frac{du}{u^2} = \frac{2g}{3c^2}\left(\frac{1}{4u^4} + \frac{C_1}{u} + C_2\right).$$

$$T(u) = -\frac{1}{c}\int \frac{du}{u^3} = \frac{1}{2cu^2} + C^2.$$

$C$, $C_1$, $C_2$, and $C_3$ are constants to be determined.

III. VELOCITIES BETWEEN 1,120 FEET AND 920 FEET.

$$F(u) = ku^6;\ k = 0.000000000000010774.$$

$$D(u) = -\frac{1}{k}\int \frac{du}{u^5} = \frac{1}{4ku^4} + K.$$

$$I(u) = -\frac{2g}{k}\int \frac{du}{u^7} = \frac{g}{3k}\left(\frac{1}{u^6} + K_1\right).$$

$$A\,(u) = -\frac{g}{3k^2}\int\left(\frac{1}{u^6}+K_1\right)\frac{du}{u^5} = \frac{g}{3k^2}\left(\frac{1}{10u^{10}}+\frac{K_1}{4u^4}+K_2\right).$$

$$T\,(u) = -\frac{1}{k}\int\frac{du}{u^6} = \frac{1}{5ku^5}+K_3.$$

$K$, $K_1$, $K_2$, and $K_3$ are constants to be determined.

IV. VELOCITIES BELOW 920 FEET.

$$F\,(u) = hu^2\left(1+\frac{u^2}{r^2}\right);\ h=0.005806,\ r=1624.4.$$

$$D\,(u) = -\frac{1}{h}\int\frac{du}{u\left(1+\frac{u^2}{r^2}\right)} = -\frac{1}{h}\int\frac{\frac{du}{u^3}}{\frac{1}{u^2}+\frac{1}{r^2}} = \frac{1}{2h}\,l\left(\frac{1}{u^2}+\frac{1}{r^2}\right)+H.$$

$$I\,(u) = -\frac{2g}{h}\int\frac{du}{u^3\left(1+\frac{u^2}{r^2}\right)} = \frac{g}{h}\int\frac{\frac{1}{u^2}\,d\,\frac{1}{u^2}}{\frac{1}{u^2}+\frac{1}{r^2}} = \frac{g}{h}\int d\,\frac{1}{u^2}-\frac{g}{hr^2}\int\frac{d\,\frac{1}{u^2}}{\frac{1}{u^2}+\frac{1}{r^2}} =$$

$$\frac{g}{h}\left[\frac{1}{u^2}-\frac{1}{r^2}\,l\left(\frac{1}{u^2}+\frac{1}{r^2}\right)+H_1\right].$$

$$A\,(u) = -\frac{g}{h^2}\int\left[\frac{1}{u^2}-\frac{1}{r^2}\,l\left(\frac{1}{u^2}+\frac{1}{r^2}\right)+H_1\right]\frac{du}{u\left(1+\frac{u^2}{r^2}\right)};$$

but $\displaystyle\int\frac{du}{u^3\left(1+\frac{u^2}{r^2}\right)} = -\frac{h}{2g}\,I\,(u),$

$$\int\frac{du}{u\left(1+\frac{u^2}{r^2}\right)} = -h\,D\,(u),$$

$$-\int l\left(\frac{1}{u^2}+\frac{1}{r^2}\right)\frac{du}{u\left(1+\frac{u^2}{r^2}\right)} = \frac{1}{2}\int l\left(\frac{1}{u^2}+\frac{1}{r^2}\right)d\,l\left(\frac{1}{u^2}+\frac{1}{r^2}\right) =$$

$$\frac{1}{4}\left[l\left(\frac{1}{u^2}+\frac{1}{r^2}\right)\right]^2;$$

we have, therefore,

$$A\,(u) = \frac{1}{2h}\,I\,(u)+\frac{gH_1}{h}\,D\,(u)-\frac{g}{4h^2r^2}\left[l\left(\frac{1}{u^2}+\frac{1}{r^2}\right)\right]^2+H_2.$$

$$T\,(u) = -\frac{1}{h}\int\frac{du}{u^2\left(1+\frac{u^2}{r^2}\right)} = \frac{1}{h}\int\frac{\frac{1}{u^2}\,d\,\frac{1}{u}}{\frac{1}{u^2}+\frac{1}{r^2}} = \frac{1}{h}\int d\,\frac{1}{u}-\frac{1}{hr^2}\int\frac{d\,\frac{1}{u}}{\frac{1}{u^2}+\frac{1}{r^2}} =$$

$$\frac{1}{h}\left[\frac{1}{u}-\frac{1}{r}\,\text{arc tang}\,\frac{r}{u}\right]+H_3.$$

$H$, $H_1$, $H_2$, and $H_3$ are constants to be determined.

## V. Determination of the sixteen arbitrary constants.

The constants Q, $Q_1$, $Q_2$, and $Q_3$ are entirely arbitrary. They could be determined so that the four functions D $(u)$, I $(u)$, A $(u)$, and T $(u)$ would reduce to zero when $u = 1{,}706$ feet.* The values that have been adopted for the quantities Q, $Q_1$, $Q_2$, and $Q_3$ satisfy this condition; but, in order to shorten the work, $Q_1$ has been made equal to zero. We have,

then, $Q = \frac{1}{q}\, l\,(2{,}200)$; $Q_2 = -\frac{1}{2\,(2{,}200)^2}$; $Q_3 = -\frac{1}{q\,(2{,}200)}$.

The other constants must be determined so that the four functions will not undergo great changes in their numerical values when they pass $u = 1{,}380$ feet, $u = 1{,}120$ feet, $u = 920$ feet.

Such being the case, we shall have for $u = 1{,}380$ feet.

$$C + \frac{1}{cu} = Q - \frac{1}{q}\, l\,(u);\ \frac{2}{3c}\left(\frac{1}{u^3} + C_1\right) = \frac{1}{qu^2},$$

$$\frac{2}{3c^2}\left(\frac{1}{4u^4} + \frac{C_1}{u} + C_2\right) = \frac{1}{q^2}\left(Q_2 + \frac{1}{2u^2}\right);\ C_3 + \frac{1}{2cu^2} = Q_3 + \frac{1}{qu}.$$

These equations give C, $C_1$, $C_2$, $C_3$.

For $u = 1{,}120$ feet, we have

$$K + \frac{1}{4ku^4} = C + \frac{1}{cu};\ \frac{1}{k}\left(K_1 + \frac{1}{u^6}\right) = \frac{2}{c}\left(C_1 + \frac{1}{u^3}\right),$$

$$\frac{1}{k^2}\left(K_2 + \frac{K_1}{4u^4} + \frac{1}{10u^{10}}\right) = \frac{2}{c^2}\left(C_2 + \frac{C_1}{u} + \frac{1}{4u^4}\right);\ K_3 + \frac{1}{5ku^5} = C_3 + \frac{1}{2cu^2}.$$

From the equations we get K, $K_1$, $K_2$, $K_3$.

Finally, we have for $u = 920$ feet,

$$H + \frac{1}{2h}\, l\left(\frac{1}{u^2} + \frac{1}{r^2}\right) = K + \frac{1}{4\,ku^4},$$

$$\frac{1}{h}\left(H_1 + \frac{1}{u^2} - \frac{1}{r^2}\, l\left(\frac{1}{u^2} + \frac{1}{r^2}\right)\right) = \frac{1}{3k}\left(K_1 + \frac{1}{u^6}\right),$$

$$H_2 - \frac{g}{4\,h^2r^2}\left[l\left(\frac{1}{u^2} + \frac{1}{r}\right)\right]^2 + \frac{g}{2h^2}\left[H_1 + \frac{1}{u^2} - \frac{1}{r^2}\, l\left(\frac{1}{u^2} + \frac{1}{r^2}\right).\right]$$

$$+ \frac{gH_1}{h}\left[H + \frac{1}{2h}\, l\left(\frac{1}{u^2} + \frac{1}{r^2}\right)\right] = \frac{g}{3k^2}\left[K^2 + \frac{K_1}{4u^4} + \frac{1}{10u^{10}}\right],$$

$$H_3 + \frac{1}{h}\left(\frac{1}{u} - \frac{1}{r}\, arc\ tang\ \frac{r}{u}\right) = K_3 + \frac{1}{5ku^5}.$$

The last constants H, $H_1$, $H_2$, and $H_3$ will be thus determined.

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*Captain Siacci has annexed to his article a ballistic table, beginning with 520 metres = 1,706 feet. In the ballistic table given in this note, D $(u)$, A $(u)$, and T $(u)$ are made equal to zero when $u = 2{,}200$ feet.—*Translator.*

## APPLICATION OF THE BALLISTIC TABLE.

### Problem I.

A projectile of a weight $p$ (in pounds) and of a diameter $a$ (in feet) is to be thrown to a distance $x$ (in feet) with the initial velocity V (in feet): Required the remaining velocity, angle of projection, angle of fall, and time of flight.

The remaining velocity will be given by the formula

$$D(v) = D(V) + \frac{100a^2}{p} x. \tag{1}$$

Look for the velocity V in the column $v$, and take from the table the values of D (V), A (V), I (V), and T (V). Calculate $\frac{100a^2}{p} x$ and obtain the value of $D(V) + \frac{100a^2}{p} x$.

After finding this value in the second column D ($v$), write out the corresponding values of $v$, A ($v$), I ($v$), and T ($v$). The remaining velocity will be $v$.

The angle of projection will be given by the expression

$$\sin 2\varphi = \left[\frac{p}{100a^2} \frac{A(v) - A(V)}{D(v) - D(V)} - I(V)\right], \tag{2}$$

and the angle of fall by the expression

$$\text{tang } \omega = \frac{p}{200a^2}\left[I(v) - \frac{A(v) - A(V)}{D(v) - D(V)}\right]\frac{1}{\cos^2\varphi}, \tag{3}$$

or approximated by

$$\sin 2\omega = \frac{p}{100a^2}\left[I(v) - \frac{A(v) - A(V)}{D(v) - D(V)}\right], \tag{4}$$

The time of flight will be obtained from the expression

$$t = \frac{p}{100a^2 \cos\varphi}[T(v) - T(V)]. \tag{5}$$

### Problem II.

At what distance will the same projectile have the velocity $v$?

From equation (1):

$$x = \frac{p}{100a^2}[D(v) - D(V)]. \tag{6}$$

### Problem III.

What initial velocity must a projectile have in order that, at the distance $x$, it shall have the velocity $v$?

Equation (1) gives

$$D(V) = D(v) - 100\frac{a^2}{p}x. \tag{7}$$

Knowing D (V), V will be found from the table.

## PROBLEM IV.

It is wished to construct a projectile of a weight and diameter to be determined, but similar to another of a weight $p$ and diameter $a$. The new projectile, with an initial velocity V, must have at the distance $x$ the velocity $v$.

Let $p'$ and $a'$ be the weight and diameter of the new projectile. Then we have

$$a' = \frac{p}{100a^2} \, \frac{D(v) - D(V)}{x} \, (8); \quad p' = \frac{p^2}{100a^2} \, \frac{D(v) - D(V)}{x}. \qquad (9)$$

### *Example I.*

The 8-inch (converted) rifle throws a shell weighing 180 pounds with an initial velocity of 1,414 feet. Required the remaining velocity, angle of projection, angle of fall, and time of flight for 1,000 yards.

Here $x = 1{,}000$ yards $= 3{,}000$ feet; $a = 8$ inches $= 0.6667$ feet; $p = 180$ pounds; $V = 1{,}414$ feet.

The ballistic table gives

$$\left.\begin{array}{l} {}^{*}D(1414) = 2{,}086.4;\ A(1{,}414) = 105.3; \\ I(1{,}414) = .07598;\ T(1{,}414) = 1.192. \end{array}\right\}$$

We also have

$$\frac{100a^2}{p} = 0.24694;$$

from which we get

$$\frac{100a^2}{p} x = 740.8.$$

$$D(1{,}414) = \frac{100a^2}{p} x = 740.8 + 2{,}086.4 = 2{,}827.2.$$

For this value sought for in the column D $(v)$, we find

$$^{\dagger}v = 1{,}218.4;\ A(v) = 171.2;\ I(v) = 0.10383;\ T(v) = 1.759.$$

The angle of projection will be given by

$$\left.\begin{array}{l} \sin 2\varphi = 4.05 \left[\dfrac{171.2 - 105.3}{2827.2 - 740.8} - .07598\right] \\ = 4.05\,[.08896 - .07598] = 4.05\,[.01298] = .052569. \end{array}\right\}$$

$$2\varphi = 3^\circ\ 1',\ \varphi = 1^\circ\ 30'.$$

---

*Since $V = 1{,}414$ feet is not in the table, it is necessary to interpolate. We will first write out D $(1{,}420) = 2{,}066$; A $(1{,}420) = 103.8$; I $(1{,}420) = .07534$; T $(1{,}420) = 1.178$. Then we solve the proportions:

$$10 : 6 :: 34 : x;\ 10 : 6 :: 2.5 : x;\ 10 : 6 :: 107 : x;\ 10 : 6 :: 24 : x.$$

Having obtained the four quantities, 20.4, 1.5, 64, 14, they must be added respectively to 2,066, 103.8, .07534, 1.178, giving the values of D (1,414), A (1,414), I (1,414), and T (1,414).

†Here, again, we must interpolate, which will be done as follows: We write V = 1,220; A $(v) = 170.5$; I $(v) = 0.10352$; T $(v) = 1.753$, which correspond to D $(v) = 2{,}820$. We have, then, the proportion $44 : 7.2 :: 10 : x = 1.6$ feet. This, subtracted from 1,220 feet, gives 1,218.4 = $^{V}$1,000 yards. We will also have the following proportions: $10 : 1.6 :: 4.6 : x$; $10 : 1.6 :: 192 : x$; $10 : 1.6 :: 36 : x$; these give 0.7, 31, 6, which must be added to 170.5, 0.10352, 1.753, respectively, giving the values of A (1,218.4), I (1,218.4), and T (1,218.4).

To determine $\omega$ we have

$$\left.\begin{aligned}\sin 2\,\omega &= 4.05\left[0.10383 - \frac{171.2 - 105.3}{2827.2 - 740.8}\right] \\ &= 4.05\,[0.10383 - 0.08896] = 4.05\,[.01487] = .059224.\end{aligned}\right\}$$

$$2\,\omega = 3^\circ\ 23'\ 40''; \quad \omega = 1^\circ\ 42'.$$

To determine $t$:

$$t = \frac{4.05}{0.99966}\left[1.759 - 1.192\right] = \frac{4.05}{0.99966}\left[0.567\right] = 2^s.295 +.$$

*Example II.*

At what distance will the same projectile have a remaining velocity of 1,200 feet?

Equation (6) gives

$$x = \frac{p}{100a^2}\,[\mathrm{D}\,(v) - \mathrm{D}\,(\mathrm{V})],$$

$$\mathrm{D}\,(v) = \mathrm{D}\,(1{,}200) = 2{,}909; \ \ \mathrm{D}\,(\mathrm{V}) = \mathrm{D}\,(1{,}414) = 2{,}080.4.$$

$$x = 4.05\,[2{,}909 - 2{,}080.4] = 405 \times 822.6 = 3{,}331.5 \text{ feet} = 1{,}110.5 \text{ yards.}$$

*Example III.*

With what initial velocity must the same projectile be thrown in order that, at a distance of 1,000 yards, it may have a remaining velocity of 1,400 feet?

Equation (7) gives

$$\mathrm{D}\,(\mathrm{V}) = \mathrm{D}\,(v) - \frac{100a^2}{p}x.$$

$$\mathrm{D}\,(v) = \mathrm{D}\,(1{,}400) = 2{,}133; \ \ \frac{100a^2}{p}x = 741.$$

$$\mathrm{D}\,(\mathrm{V}) = 2{,}133 - 741 = 1{,}392. \quad \mathrm{V} = 1{,}638 \text{ feet.}$$

*Example IV.*

Let it be supposed that the charge, giving the initial velocity of 1,414 feet, cannot be increased without compromising the safety of the gun, and, on the other hand, that it is necessary to have, at 6,000 yards distance, a remaining velocity of 840 feet. We will see what result will be obtained if we increase a little the weight of the projectile.

We will find first how much the initial velocity will be diminished if the weight of the projectile be increased to 200 pounds.

Hutton's law gives

$$p'\,\mathrm{V}' = p\,\mathrm{V}^2,$$

or

$$\mathrm{V}' = \mathrm{V}\sqrt{\frac{p}{p'}} = 1{,}414\sqrt{\frac{180}{200}} = 1{,}414 \times 0.9487 = 1{,}341 \text{ feet,}$$

and from the ballistic table,

$$\mathrm{D}\,(1{,}341) = 2{,}338.$$

Also,

$$\frac{100a^2}{p} = 0.2223,$$

and for

$$x = 6{,}000 \text{ yards}, 100\,\frac{a^2}{p}\,x = 4{,}001;$$

consequently

$$\mathrm{D}\,(v) = 2{,}338 + 4{,}001 = 6{,}339,$$

and, from the table,

$$v = 836 \text{ feet.}$$

This result differs but little from the required velocity; but Hutton's law is true only when the powder is completely consumed before the projectile leaves the gun, and in practice we might obtain a greater difference. We will see what velocity will be obtained if the weight of the projectile be increased to 210 pounds. Calculation gives for the initial velocity

$$1{,}309 \text{ feet, and D } (1{,}309) = 2{,}458.$$

Then

$$\frac{100a^2}{p} \times x = 0.2117 \times 18{,}000 = 3{,}811;$$

and

$$\mathrm{D}\,(v) = 3{,}811 + 2{,}458 = 6{,}269,$$

which corresponds to

$$v = 840 \text{ feet.}$$

The following formulas can be employed for calculating the initial velocity V when experiment has determined the velocity $v$ at a short distance $x$:

For velocities between 1,710 feet and 1,380 feet,

$$\mathrm{V} = v\,(1 + q\,x);\ q = 0.021184\,\frac{a^2}{p}.$$

For velocities between 1,380 feet and 1,120 feet,

$$\mathrm{V} = v\,(1 + c\,v\,x);\ c = 0.000015373\,\frac{a^2}{p}.$$

For velocities between 1,120 feet and 920 feet,

$$\mathrm{V} = v\,(1 + k\,v^4\,x);\ k = 0.00000000000010774\,\frac{a^2}{p}.$$

For velocities below 920 feet,

$$\mathrm{V} = v\left(1 + \left(1 + \frac{v^2}{r^2}\right)h\,x\right), r = 1.624.4,\ h = 0.005806\,\frac{a^2}{p}.$$

These formulas are obtained from the expression for the resistance of the air given in section 6.

The following theoretical range tables have been calculated from Captain Siacci's formulas:

## RANGE TABLES.

### 8-inch rifle (converted).

Charge, 35 lbs. Weight of shot, 180 lbs. Initial velocity, 1,414 feet.

| Range. | Remaining velocity. | Angle of projection. | Angle of fall. | Time of flight. |
|---|---|---|---|---|
| | *Feet.* | ° ′ | ° ′ ″ | *s.* |
| 500 yards | 1,309 | 0 44 | 0 46 15 | 1.14 |
| 1,000 yards | 1,218 | 1 30 | 1 42 | 2.30 |
| 1,500 yards | 1,139 | 2 25 | 2 49 | 3.58 |
| 2,000 yards | 1,073 | 3 26 | 4 6 | 4.96 |
| 3,000 yards | 982 | 5 43 | 7 3 | 7.93 |
| 4,000 yards | 921 | 8 14 | 11 1 | 11.11 |
| 5,000 yards | 870 | 11 23 | 15 33 | 14.69 |
| 6,000 yards | 824 | 14 48 | 21 19 | 18.54 |
| 7,000 yards | 781 | 18 50 | 29 40 | 22.94 |
| 8,000 yards | 741 | 23 51 | 34 51 | 28.01 |

### 12-inch B. L. rifle. (Proposed model.)

Charge, 290 lbs. Weight of shot, 800 lbs. Initial velocity, 1,886 feet.

| | | | | |
|---|---|---|---|---|
| | *Feet.* | ° ′ ″ | ° ′ ″ | *s.* |
| 500 yards | 1,818 | 0 23 27 | 0 24 57 | 0.81 |
| 1,000 yards | 1,742 | 0 49 17 | 0 51 45 | 1.66 |
| 1,500 yards | 1,674 | 1 15 | 1 23 | 2.54 |
| 2,000 yards | 1,609 | 1 44 | 1 56 | 3.45 |
| 3,000 yards | 1,486 | 2 46 | 3 14 | 5.39 |
| 4,000 yards | 1,378 | 3 53 | 4 50 | 7.50 |
| 5,000 yards | 1,272 | 5 10 | 6 47 | 9.80 |
| 6,000 yards | 1,185 | 6 38 | 9 8 | 12.30 |
| 7,000 yards | 1,110 | 8 14 | 11 56 | 14.96 |
| 8,000 yards | 1,051 | 10 2 | 15 20 | 17.85 |
| 9,000 yards | 1,004 | 12 10 | 19 27 | *21.03 |
| 10,000 yards | 967 | 14 28 | 24 26 | 24.33 |

Captain Siacci gives as the type of the arrangement of a calculation the following form:

### CALCULATION OF TABLE OF FIRE FOR 12-INCH B. L. RIFLE.

| V = 1,886 feet. | $a = 12'' = 1$ foot. | $p = 800$ pounds. |
|---|---|---|
| Distance $x$. | 1,000 yards = 3,000 feet. | 2,000 yards = 6,000 feet. |
| Log $x$. | 3.4771213 | 3.7781513 |
| Log $100\frac{a^2}{p}$. | $\bar{1}.0969100$ | $\bar{1}.0969100$ |
| Log $100\frac{a^2}{p}x$. | 2.5740313 | 2.8750613 |
| $100\frac{a^2}{p}x$. | 375. | 750. |
| D (1,886). | 726.6 | 726.6 |
| $100\frac{a^2}{p}x + D$ (1,886). | 1101.6 | 1476.6 |
| A ($v$). | 44.08 | 64.42 |
| A (V). | 26.72 | 26.72 |

CALCULATION OF TABLE OF FIRE FOR 12-INCH B. L. RIFLE—Continued.

| $V = 1{,}886$ feet. | $a = 12'' = 1$ foot. | $p = 800$ pounds. |
|---|---|---|
| Distance $x$. | 1,000 yards = 3,000 feet. | 2,000 yards = 6,000 feet. |
| $A(v) - A(V)$. | 17.36 | 37.70 |
| Log $[A(v) - A(V)]$. | 1.2395497 | 1.5763414 |
| (a. c.) Log. $\left[100\frac{a^2}{p}x = D(v) - D(V)\right]$ | 7.4259687 | 7.1249387 |
| Log $\frac{p}{100a^2}$. | 0.9030900 | 0.9030900 |
| Log $\frac{A(v) - A(V)}{D(v) - D(V)} \times \frac{p}{100a^2}$. | $\bar{1}$.5686084 | $\bar{1}$.6043701 |
| $\frac{A(v) - A(V)}{D(v) - D(V)} \times \frac{p}{100a^2}$. | 0.370347 | 0.402133 |
| $I(V) \times \frac{p}{100a^2}$. | 0.341680 | 0.341680 |
| $\sin 2\phi$. | 0.028667 | 0.060453 |
| $\phi$. | 49′ 17″ | 1° 43′ 59″ |
| $I(v)$. | 0.050056 | 0.058674 |
| Log $I(v)$. | $\bar{2}$.6994561 | $\bar{2}$.7684457 |
| Log $\frac{p}{100a^2}$. | 0.9030900 | 0.9030900 |
| Log $\left[I(v) \times \frac{p}{100a^2}\right]$. | $\bar{1}$.6025461 | $\bar{1}$.6715357 |
| $I(v) \times \frac{p}{100a^2}$. | 0.400448 | 0.469392 |
| $\frac{p}{100a^2}\frac{A(v) - A(V)}{D(v) - D(V)}$. | 0.370347 | 0.402133 |
| $\sin 2\omega$. | 0.030101 | 0.067259 |
| $\omega$. | 51′ 45″ | 1° 55′ 42″ |
| $T(v)$. | 0.5642 | 0.7881 |
| $T(V)$. | 0.3572 | 0.3572 |
| $T(v) - T(V)$. | 0.2070 | 0.4309 |
| Log $[T(v) - T(V)]$. | $\bar{1}$.3159703 | $\bar{1}$.6343765 |
| (a. c.) Log $\cos\phi$. | 0.0000478 | 0.0001985 |
| Log $\frac{p}{100a^2}$. | 0.9030900 | 0.9030900 |
| Log $t$. | 0.2191081 | 0.5376650 |
| $t$. | 1ˢ.656 | 3ˢ.449 |
| $v$. | 1,742 feet. | 1,609 feet. |

## BALLISTIC TABLE CALCULATED FROM CAPTAIN SIACCI'S FORMULAS.

| *v.* | D (*v*) | Diff. | A (*v*) | Diff. | I (*v*) | Diff. | T (*v*) | Diff. |
|---|---|---|---|---|---|---|---|---|
| *Feet.* 2200 | 0 | 21 | 0 | 68 | .03139 | 28 | 0 | 98 |
| 2190 | 21 | 22 | 0.68 | 69 | .03167 | 29 | .0098 | 99 |
| 2180 | 43 | 21 | 1.37 | 70 | .03196 | 30 | .0197 | 100 |
| 2170 | 64 | 22 | 2.07 | 71 | .03226 | 30 | .0297 | 101 |
| 2160 | 86 | 22 | 2.78 | 72 | .03256 | 30 | .0398 | 102 |
| 2150 | 108 | 22 | 3.50 | 73 | .03286 | 31 | .0500 | 103 |
| 2140 | 130 | 22 | 4.23 | 74 | .03317 | 31 | .0603 | 104 |
| 2130 | 152 | 23 | 4.97 | 75 | .03348 | 32 | .0707 | 104 |
| 2120 | 175 | 22 | 5.72 | 76 | .03380 | 32 | .0811 | 105 |
| 2110 | 197 | 22 | 6.48 | 77 | .03412 | 33 | .0916 | 106 |
| 2100 | 219 | 23 | 7.25 | 78 | .03445 | 33 | .1022 | 108 |
| 2090 | 242 | 22 | 8.03 | 79 | .03478 | 33 | .1130 | 109 |
| 2080 | 264 | 23 | 8.82 | 80 | .03511 | 34 | .1239 | 110 |
| 2070 | 287 | 23 | 9.62 | 81 | .03545 | 35 | .1349 | 111 |
| 2060 | 310 | 23 | 10.43 | 83 | .03580 | 35 | .1460 | 111 |
| 2050 | 333 | 23 | 11.26 | 84 | .03615 | 35 | .1571 | 113 |
| 2040 | 356 | 23 | 12.10 | 85 | .03650 | 36 | .1684 | 114 |
| 2030 | 379 | 24 | 12.95 | 86 | .03686 | 37 | .1798 | 115 |
| 2020 | 403 | 23 | 13.81 | 88 | .03723 | 37 | .1913 | 116 |
| 2010 | 426 | 24 | 14.69 | 89 | .03760 | 38 | .2029 | 117 |
| 2000 | 450 | 23 | 15.58 | 90 | .03798 | 38 | .2146 | 118 |
| 1990 | 473 | 24 | 16.48 | 91 | .03836 | 39 | .2264 | 120 |
| 1980 | 497 | 24 | 17.39 | 93 | .03875 | 39 | .2384 | 121 |
| 1970 | 521 | 24 | 18.32 | 95 | .03914 | 40 | .2505 | 122 |
| 1960 | 545 | 24 | 19.27 | 96 | .03954 | 41 | .2627 | 124 |
| 1950 | 569 | 24 | 20.23 | 97 | .03995 | 41 | .2751 | 125 |
| 1940 | 593 | 25 | 21.20 | 99 | .04036 | 42 | .2876 | 126 |
| 1930 | 618 | 24 | 22.19 | 1.00 | .04078 | 43 | .3002 | 127 |
| 1920 | 642 | 25 | 23.19 | 1.02 | .04121 | 43 | .3129 | 129 |
| 1910 | 667 | 25 | 24.21 | 1.03 | .04164 | 44 | .3258 | 130 |
| 1900 | 692 | 25 | 25.24 | 1.05 | .04208 | 45 | .3388 | 131 |
| 1890 | 717 | 24 | 26.29 | 1.07 | .04253 | 45 | .3519 | 133 |
| 1880 | 741 | 26 | 27.36 | 1.09 | .04298 | 46 | .3652 | 134 |
| 1870 | 767 | 25 | 28.45 | 1.11 | .04344 | 47 | .3786 | 136 |
| 1860 | 792 | 26 | 29.56 | 1.12 | .04391 | 48 | .3922 | 137 |
| 1850 | 818 | 25 | 30.68 | 1.14 | .04439 | 48 | .4059 | 139 |
| 1840 | 843 | 26 | 31.82 | 1.16 | .04487 | 49 | .4198 | 140 |
| 1830 | 869 | 26 | 32.98 | 1.18 | .04536 | 50 | .4338 | 142 |
| 1820 | 895 | 26 | 34.16 | 1.20 | .04586 | 51 | .4480 | 143 |
| 1810 | 921 | 26 | 35.36 | 1.22 | .04637 | 52 | .4623 | 145 |

BALLISTIC TABLE—Continued.

| v. | D (v) | Diff. | A (v) | Diff. | I (v) | Diff. | T (v) | Diff. |
|---|---|---|---|---|---|---|---|---|
| *Feet.* 1800 | 947 | | 36.58 | | .04689 | | .4768 | |
| | | 26 | | 1.24 | | 52 | | 147 |
| 1790 | 973 | | 37.82 | | .04741 | | .4915 | |
| | | 27 | | 1.26 | | 53 | | 148 |
| 1780 | 1000 | | 39.08 | | .04794 | | .5063 | |
| | | 27 | | 1.28 | | 55 | | 150 |
| 1770 | 1027 | | 40.36 | | .04849 | | .5213 | |
| | | 26 | | 1.31 | | 55 | | 152 |
| 1760 | 1053 | | 41.67 | | 04904 | | .5365 | |
| | | 27 | | 1.33 | | 56 | | 153 |
| 1750 | 1080 | | 43.00 | | .04960 | | .5518 | |
| | | 27 | | 1.35 | | 57 | | 155 |
| 1740 | 1107 | | 44.35 | | .05017 | | .5673 | |
| | | 27 | | 1.37 | | 58 | | 157 |
| 1730 | 1134 | | 45.72 | | .05075 | | .5830 | |
| | | 27 | | 1.40 | | 60 | | 159 |
| 1720 | 1162 | | 47.12 | | .05135 | | .5989 | |
| | | 27 | | 1.42 | | 60 | | 160 |
| 1710 | 1189 | | 48.54 | | .05195 | | .6149 | |
| | | 28 | | 1.44 | | 61 | | 162 |
| 1700 | 1217 | | 49.98 | | .05256 | | .6311 | |
| | | 28 | | 1.48 | | 63 | | 164 |
| 1690 | 1245 | | 51.46 | | .05319 | | .6475 | |
| | | 28 | | 1.49 | | 63 | | 166 |
| 1680 | 1273 | | 52.95 | | .05382 | | .6641 | |
| | | 28 | | 1.53 | | 65 | | 168 |
| 1670 | 1301 | | 54.48 | | .05447 | | .6809 | |
| | | 28 | | 1.55 | | 66 | | 170 |
| 1660 | 1329 | | 56.03 | | .05513 | | .6979 | |
| | | 29 | | 1.59 | | 67 | | 172 |
| 1650 | 1358 | | 57.62 | | .05580 | | .7151 | |
| | | 28 | | 1.61 | | 68 | | 175 |
| 1640 | 1386 | | 59.23 | | .05648 | | .7326 | |
| | | 29 | | 1.64 | | 70 | | 177 |
| 1630 | 1415 | | 60.87 | | .05718 | | .7503 | |
| | | 29 | | 1.67 | | 70 | | 179 |
| 1620 | 1444 | | 62.54 | | .05788 | | .7682 | |
| | | 30 | | 1.70 | | 72 | | 181 |
| 1610 | 1474 | | 64.24 | | .05860 | | .7863 | |
| | | 29 | | 1.74 | | 74 | | 183 |
| 1600 | 1503 | | 65.98 | | .05934 | | .8046 | |
| | | 30 | | 1.76 | | 75 | | 185 |
| 1590 | 1533 | | 67.74 | | .06009 | | .8231 | |
| | | 29 | | 1.80 | | 76 | | 189 |
| 1580 | 1562 | | 69.54 | | .06085 | | .8420 | |
| | | 30 | | 1.84 | | 78 | | 190 |
| 1570 | 1592 | | 71.38 | | .06163 | | .8610 | |
| | | 30 | | 1.87 | | 79 | | 193 |
| 1560 | 1622 | | 73.25 | | .06242 | | .8803 | |
| | | 31 | | 1.91 | | 81 | | 195 |
| 1550 | 1653 | | 75.16 | | .06323 | | .8998 | |
| | | 30 | | 1.94 | | 82 | | 198 |
| 1540 | 1683 | | 77.10 | | .06405 | | .9196 | |
| | | 31 | | 1.98 | | 84 | | 200 |
| 1530 | 1714 | | 79.08 | | .06489 | | .9396 | |
| | | 31 | | 2.03 | | 86 | | 203 |
| 1520 | 1745 | | 81.11 | | .06575 | | .9599 | |
| | | 31 | | 2.06 | | 87 | | 206 |
| 1510 | 1776 | | 83.17 | | .06662 | | .9805 | |
| | | 32 | | 2.10 | | 89 | | 21 |
| 1500 | 1808 | | 85.27 | | .06751 | | 1.001 | |
| | | 31 | | 2.15 | | 91 | | 21 |
| 1490 | 1829 | | 87.42 | | .06842 | | 1.022 | |
| | | 32 | | 2.19 | | 93 | | 21 |
| 1480 | 1871 | | 89.61 | | .06935 | | 1.043 | |
| | | 32 | | 2.23 | | 95 | | 22 |
| 1470 | 1903 | | 91.84 | | .07030 | | 1.065 | |
| | | 32 | | 2.28 | | 96 | | 22 |
| 1460 | 1935 | | 94.12 | | .07126 | | 1.087 | |
| | | 33 | | 2.33 | | 99 | | 22 |
| 1450 | 1968 | | 96.45 | | .07225 | | 1.109 | |
| | | 32 | | 2.38 | | 101 | | 23 |
| 1440 | 2000 | | 98.83 | | .07326 | | 1.132 | |
| | | 33 | | 2.43 | | 103 | | 23 |
| 1430 | 2033 | | 101.3 | | .07429 | | 1.155 | |
| | | 33 | | 2.5 | | 105 | | 23 |
| 1420 | 2066 | | 103.8 | | .07534 | | 1.178 | |
| | | 34 | | 2.5 | | 07 | | 24 |
| 1410 | 2100 | | 106.3 | | .07641 | | 1.202 | |
| | | 33 | | 2.6 | | 109 | | 24 |

BALLISTIC TABLE—Continued.

| v. | D (v) | Diff. | A (v) | Diff. | I (v) | Diff. | T (v) | Diff. |
|---|---|---|---|---|---|---|---|---|
| *Feet.* 1400 | 2133 | 34 | 108.9 | 2.6 | .07750 | 112 | 1.226 | 24 |
| 1390 | 2167 | 34 | 111.5 | 2.7 | .07862 | 115 | 1.250 | 25 |
| 1380 | 2201 | 34 | 114.2 | 2.8 | .07977 | 117 | 1.275 | 25 |
| 1370 | 2235 | 35 | 117.0 | 2.8 | .08094 | 121 | 1.300 | 26 |
| 1360 | 2270 | 36 | 119.8 | 2.9 | .08215 | 124 | 1.326 | 26 |
| 1350 | 2306 | 36 | 122.7 | 3.0 | .08339 | 128 | 1.352 | 27 |
| 1340 | 2342 | 37 | 125.7 | 3.1 | .08467 | 132 | 1.379 | 27 |
| 1330 | 2379 | 37 | 128.8 | 3.2 | .08599 | 136 | 1.406 | 28 |
| 1320 | 2416 | 38 | 132.0 | 3.3 | .08735 | 140 | 1.434 | 29 |
| 1310 | 2454 | 38 | 135.3 | 3.4 | .08875 | 144 | 1.463 | 29 |
| 1300 | 2492 | 39 | 138.7 | 3.5 | .09019 | 149 | 1.492 | 30 |
| 1290 | 2531 | 39 | 142.2 | 3.6 | .09168 | 153 | 1.522 | 31 |
| 1280 | 2570 | 40 | 145.8 | 3.8 | .09321 | 159 | 1.553 | 31 |
| 1270 | 2610 | 41 | 149.6 | 3.9 | .09480 | 163 | 1.584 | 32 |
| 1260 | 2651 | 41 | 153.5 | 4.0 | .09643 | 169 | 1.616 | 33 |
| 1250 | 2692 | 42 | 157.5 | 4.2 | .09812 | 174 | 1.649 | 34 |
| 1240 | 2734 | 43 | 161.7 | 4.3 | .09986 | 180 | 1.683 | 35 |
| 1230 | 2777 | 43 | 166.0 | 4.5 | .10166 | 186 | 1.718 | 35 |
| 1220 | 2820 | 44 | 170.5 | 4.6 | .10352 | 192 | 1.753 | 36 |
| 1210 | 2864 | 45 | 175.1 | 4.7 | .10544 | 197 | 1.789 | 38 |
| 1200 | 2909 | 45 | 179.8 | 4.9 | .10741 | 205 | 1.827 | 38 |
| 1190 | 2954 | 47 | 184.7 | 5.2 | .10948 | 213 | 1.865 | 39 |
| 1180 | 3001 | 47 | 189.9 | 5.3 | .11161 | 219 | 1.904 | 40 |
| 1170 | 3048 | 48 | 195.2 | 5.5 | .11380 | 228 | 1.944 | 41 |
| 1160 | 3096 | 48 | 200.7 | 5.7 | .11608 | 235 | 1.985 | 42 |
| 1150 | 3144 | 50 | 206.4 | 5.9 | .11843 | 243 | 2.027 | 43 |
| 1140 | 3194 | 51 | 212.3 | 6.2 | .12086 | 253 | 2.070 | 44 |
| 1130 | 3245 | 52 | 218.5 | 6.4 | .12339 | 261 | 2.114 | 46 |
| 1120 | 3297 | 53 | 224.9 | 6.9 | .12600 | 273 | 2.160 | 48 |
| 1110 | 3350 | 56 | 231.8 | 7.3 | .12873 | 297 | 2.208 | 51 |
| 1100 | 3406 | 59 | 239.1 | 7.9 | .13170 | 316 | 2.259 | 54 |
| 1090 | 3465 | 62 | 247.0 | 8.4 | .13486 | 338 | 2.313 | 57 |
| 1080 | 3527 | 65 | 255.4 | 9.0 | .13824 | 360 | 2.370 | 60 |
| 1070 | 3592 | 68 | 264.4 | 9.7 | .14184 | 384 | 2.430 | 64 |
| 1060 | 3660 | 71 | 274.1 | 10.5 | .14568 | 411 | 2.494 | 67 |
| 1050 | 3731 | 74 | 284.6 | 11.3 | .14979 | 439 | 2.561 | 71 |
| 1040 | 3805 | 78 | 295.9 | 12.2 | .15418 | 470 | 2.632 | 76 |
| 1030 | 3883 | 82 | 308.1 | 13.2 | .15888 | 502 | 2.708 | 80 |
| 1020 | 3965 | 86 | 321.3 | 14.4 | .16390 | 539 | 2.788 | 85 |
| 1010 | 4051 | 90 | 335.7 | 15.6 | .16929 | 577 | 2.873 | 90 |

BALLISTIC TABLE—Continued.

| v. | D (v) | Diff. | A (v) | Diff. | I (v) | Diff. | T (v) | Diff. |
|---|---|---|---|---|---|---|---|---|
| *Feet.* | | | | | | | | |
| 1000 | 4141 | 95 | 351.3 | 17.0 | .17506 | .618 | 2.963 | 95 |
| 990 | 4236 | 100 | 368.3 | 18.5 | .18124 | 665 | 3.058 | 102 |
| 980 | 4336 | 105 | 386.8 | 20.2 | .18789 | 713 | 3.160 | 108 |
| 970 | 4441 | 111 | 407.0 | 22.1 | .19502 | 765 | 3.268 | 115 |
| 960 | 4552 | 117 | 429.1 | 24.1 | .20167 | 815 | 3.383 | 122 |
| 950 | 4669 | 123 | 453.2 | 26.6 | .21082 | 885 | 3.505 | 131 |
| 940 | 4792 | 130 | 479.8 | 29.2 | .21967 | 964 | 3.636 | 139 |
| 930 | 4922 | 137 | 509.0 | 32.1 | .22931 | 1031 | 3.775 | 148 |
| 920 | 5059 | 143 | 541.1 | 36.3 | .23962 | 1101 | 3.923 | 156 |
| 910 | 5202 | 145 | 577.4 | 37.1 | .25063 | 1141 | 4.079 | 160 |
| 900 | 5347 | 148 | 614.5 | 39.4 | .26204 | 1185 | 4.239 | 165 |
| 890 | 5495 | 150 | 653.9 | 42.3 | .27389 | 1233 | 4.404 | 170 |
| 880 | 5645 | 153 | 696.2 | 44.6 | .28622 | 1281 | 4.574 | 174 |
| 870 | 5798 | 155 | 740.8 | 47.3 | .29903 | 1334 | 4.748 | 179 |
| 860 | 5953 | 158 | 788.1 | 50.6 | .31237 | 1389 | 4.927 | 185 |
| 850 | 6111 | 160 | 838.7 | 53.6 | .32626 | 1444 | 5.112 | 190 |
| 840 | 6271 | 163 | 892.3 | 56.6 | .34070 | 1506 | 5.302 | 195 |
| 830 | 6434 | 166 | 948.9 | 60.1 | .35576 | 1568 | 5.497 | 202 |
| 820 | 6600 | 169 | 1009.0 | 64 | .37144 | 1636 | 5.699 | 207 |
| 810 | 6769 | 172 | 1073 | 68 | .38780 | 1704 | 5.906 | 214 |
| 800 | 6941 | 175 | 1141 | 72 | .40484 | 1779 | 6.120 | 220 |
| 790 | 7116 | 178 | 1213 | 77 | .42263 | 1857 | 6.340 | 227 |
| 780 | 7294 | 181 | 1290 | 81 | .44120 | 1939 | 6.567 | 233 |
| 770 | 7475 | 184 | 1371 | 87 | .46059 | 2026 | 6.800 | 241 |
| 760 | 7659 | 188 | 1458 | 92 | .48085 | 2117 | 7.041 | 248 |
| 750 | 7847 | 191 | 1550 | 98 | .50202 | 2212 | 7.289 | 256 |
| 740 | 8038 | 194 | 1648 | 105 | .52414 | 2318 | 7.545 | 265 |
| 730 | 8232 | 198 | 1753 | 111 | .54732 | 2424 | 7.810 | 273 |
| 720 | 8430 | 202 | 1864 | 118 | .57156 | 2539 | 8.083 | 282 |
| 710 | 8632 | 206 | 1982 | 125 | .59695 | 2661 | 8.365 | 292 |
| 700 | 8838 | 210 | 2107 | 133 | .62356 | 2789 | 8.657 | 301 |
| 690 | 9048 | 213 | 2240 | 142 | .65145 | 2927 | 8.958 | 312 |
| 680 | 9261 | 217 | 2382 | 153 | .68072 | 3073 | 9.270 | 322 |
| 670 | 9478 | 222 | 2534 | 161 | .71145 | 3226 | 9.592 | 334 |
| 660 | 9700 | 226 | 2695 | 172 | .74371 | 3392 | 9.926 | 345 |
| 650 | 9926 | 231 | 2867 | 183 | .77763 | 3566 | 10.271 | 358 |
| 640 | 10157 | 345 | 3050 | 196 | .81329 | 3752 | 10.629 | 371 |
| 630 | 10392 | 240 | 3246 | 209 | .85081 | 3955 | 11.000 | 384 |
| 620 | 10632 | 245 | 3455 | 223 | .89036 | 4165 | 11.384 | 398 |
| 610 | 10877 | 250 | 3678 | 239 | .93201 | 4395 | 11.782 | 413 |

## BALLISTIC TABLE—Continued.

| *v*. | D (*v*) | Diff. | A (*v*) | Diff. | I (*v*) | Diff. | T (*v*) | Diff. |
|---|---|---|---|---|---|---|---|---|
| *Feet.* 600 | 11127 | | 3917 | | .9760 | | 12.195 | |
| | | 255 | | 255 | | 463 | | 429 |
| 590 | 11382 | | 4172 | | 1.0223 | | 12.624 | |
| | | 261 | | 273 | | 490 | | 446 |
| 580 | 11643 | | 4445 | | 1.0713 | | 13.070 | |
| | | 266 | | 292 | | 518 | | 463 |
| 570 | 11909 | | 4737 | | 1.1231 | | 13.533 | |
| | | 272 | | 313 | | 548 | | 482 |
| 560 | 12181 | | 5050 | | 1.1779 | | 14.015 | |
| | | 278 | | 335 | | 581 | | 501 |
| 550 | 12459 | | 5385 | | 1.2360 | | 14.516 | |
| | | 284 | | 360 | | 615 | | 521 |
| 540 | 12743 | | 5745 | | 1.2975 | | 15.037 | |
| | | 292 | | 389 | | 657 | | 544 |
| 530 | 13035 | | 6134 | | 1.3632 | | 15.581 | |
| | | 295 | | 412 | | 689 | | 564 |
| 520 | 13330 | | 6546 | | 1.4321 | | 16.145 | |
| | | 304 | | 447 | | 737 | | 590 |
| 510 | 13634 | | 6993 | | 1.5058 | | 16.735 | |
| | | 311 | | 481 | | 785 | | 616 |
| 500 | 13945 | | 7474 | | 1.5843 | | 17.351 | |

# APPENDIX 24.

## REPORT ON FEED-GUIDES AND FEED-CASES FOR MACHINE GUNS, AND METHODS OF PACKING THE AMMUNITION FOR TRANSPORTATION. BY CAPT. JOHN E. GREER (UNDER THE DIRECTION OF COL. JAMES G. BENTON, COMMANDING THE NATIONAL ARMORY).

[Twenty plates.]

NATIONAL ARMORY, SPRINGFIELD, MASS.,
*June* 10, 1880.

SIR: After careful consideration of the methods by which the various machine-guns now in service are supplied or fed with cartridges, I am led to the conclusion that the time has come for abandoning that adapted for the Gatling in the infancy, it may be said, of guns of this class.

The present system necessitates the use of tin feed-cases containing 40 cartridges each, 50 cases being issued with each gun. The limber-chest of the carriage as made at the Colt's armory being limited to this number of cases, 2,000 rounds is consequently the extent of its carrying capacity. As made at the United States Watervliet arsenal the gun-carriage itself carries two small-chests parallel with the gun, by which means an auxiliary amount of ammunition may be transported. As the new system of elevating and pointing the gun prohibits the use of these two chests—the gun being traversed from right to left so as to come nearly in contact with the wheels—they must be omitted in future comparisons.

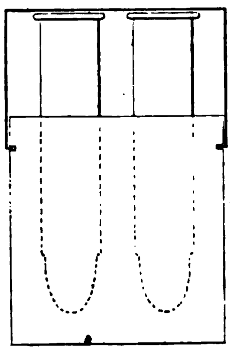
The Gatling feed-cases weigh 2 pounds 4½ ounces and cost $2 each. In them the cartridges are jolted about on the march, the shells are bruised, and the bullets mutilated and upset, so as to affect not only the accuracy of fire but the working of the gun. The objection to the tin feed cases does not end here, as in action they must be refilled from the paper packages in which the cartridges are prepared at an arsenal, and this requires the service of several men, though the gun be worked at a moderate percentage of its capability of fire. In addition, there is no stability of the case on the gun, since cutting away the rear portion of the hopper-mouth in order to admit of ready insertion of the case left but little to support it, necessitating its being held at all times when in use. Finally, a filled case once having been applied to the gun cannot be removed except with considerable difficulty, without allowing the cartridges to fall on the ground, should it become necessary to move the gun to any other position.

To meet the objections here enumerated I would bring to your notice two methods proposed for the Gardner guns now being made for the United States at the Pratt & Whitney Works, Hartford, Conn. In the first, as tested by the Ordnance Board at Sandy Hook, N. J., the cartridges were inserted in wooden blocks bored to receive 20 n two rows of 10 each. The blocks were somewhat larger than the packages in which cartridges are packed at Frankford arsenal.

The cartridges were retained in their places by a strip of tin passing

over their heads and bent down at the sides, the edges again being turned in so as to enter channels in the sides of the blocks, thus:

END VIEW.




The blocks were light, easily filled, cheap—not costing more than two or three cents each,—and took up so little room that 3,400 cartridges could be carried in a limber-chest of the capacity of the Gatling, which carries, as before stated, but 2,000 rounds. In addition, the interior arrangement of the chest was such as to be materially cheaper than the Gatling. To feed from these blocks it is only necessary to slide off the tin cover, insert the heads of the cartridges in the "feed-guide" and pull the blocks from the cartridges which are held by their heads in the guide. By this means the guide may be kept full, giving a continuous stream of fire, while in the Gatling the fire is intermittent, depending on the rapidity with which the cases can be changed.

The feed-guide of the Gardner is practically the hopper of the Gatling (Plate II, Figs. 1 and 2), and is securely attached to the gun when in use. Should it be desired to change the position of the gun the guide need not necessarily be removed, but if it be, an automatic arrangement closes its lower end and prevents escape of cartridges.

Since the trial previously referred to, the company have devised a plan, if anything, more desirable than that described, and which brings the carrying capacity of the limber up to 4,200 rounds. It is, in fact, to put up at the place of manufacture the cartridges intended for this gun in paper boxes differing but little in exterior form and size from those now used at Frankford.

It is proposed to make the boxes in two equal parts (see Plate I), pressing them from paper pulp. The two parts are united by a strip of muslin glued on the bottom. A pasteboard strip is then placed midway between the sides and the cartridges filled in, and the tin cover slipped on. A second strip of muslin is glued on the bottom, carried up one end over the top and down the other end, projecting three or four inches, for convenience in opening the box. A paper-wrapper is pasted over all and varnished to prevent moisture.

To feed from these boxes it is only necessary to tear them open by the muslin strip, pull off the tin cover, and insert the heads of the cartridges in the feed-guide as with the original blocks. It is estimated by the company that these boxes will not cost over five cents each.

When it is recollected that the cartridges must be packed anyway in paper boxes costing two or three cents each, it will be seen how great the saving by this method is. While the putting up of the cartridges in a special manner at an arsenal may be considered objectionable, the system of feeding directly from the paper packages is so economical in cost, weight, time, and men as to far outweigh the objection. These boxes can be refilled, if necessary, from the ordinary box, omitting the outside paper wrapping and muslin string, when they become to all intents and purposes the same as the original wooden blocks tested with the gun.

The system of feeding from the paper boxes has been adapted for the Lowell battery gun, and there would seem to be no good reason why it should not be for the Gatling. The rapidity of its fire would be greatly increased, the construction of the limber-chest simplified, and its capac-

ity more than doubled without increase of weight and with a diminished cost of about $100, a stable form of attachment to the gun provided, and the service of several men dispensed with.

In order to attain this end without interfering with the rights of others any particular form of box may be used at the pleasure of the company. If necessary, one-half as long as the feed-case—that is, half the depth of the limber-chest—containing 20 cartridges in a single row, or 40 in two rows, could be used.

In any event the feed-case should be abandoned. We have steadily improved the construction of the gun, changed from side to center feed, and increased the pitch of the gearing to increase the rapidity of fire, but have heretofore neglected one of the simplest means of accomplishing this end.

Very respectfully, your obedient servant,

JOHN E. GREER,
*Captain of Ordnance, U. S. A.*

To the COMMANDING OFFICER, NATIONAL ARMORY.

[*First indorsement.*]

NATIONAL ARMORY, *June* 22, 1880.

Respectfully forwarded to the Chief of Ordnance:

The suggestions of Captain Greer, given in this communication, are thought to be worthy of consideration by the department.

J. G. BENTON,
*Colonel of Ordnance, Commanding.*

[*Second indorsement.*]

ORDNANCE OFFICE, WAR DEPARTMENT,
*Washington, June* 24, 1880.

Respectfully returned to the commanding officer of National Armory, who will request the Gatling Gun Company to apply this method of feeding to one of the guns recently made and delivered. Captain Greer's views are sound and timely, and the question of supply of cartridges is so important that every means should be resorted to to increase the quantity carried.

S. V. BENÉT,
*Brigadier General, Chief of Ordnance.*

[*Third indorsement.*]

NATIONAL ARMORY, *June* 16, 1881.

Respectfully returned to the Chief of Ordnance:

As the Gatling Gun Company was not disposed to take up this matter, I thought it of sufficient importance to make the trial at this armory, a report of which, by Captain Greer, is this day forwarded for the information of the department.

J. G. BENTON,
*Colonel of Ordnance, Commanding.*

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NATIONAL ARMORY, SPRINGFIELD, MASS.,
*June* 6, 1881.

SIR: After my report of June 10, 1880, calling attention to a new feed-block or case for the Gardner machine gun, by which the capacity of the

limber-chest was brought up to 4,200 rounds, and suggesting that the system of feeding this gun by the double guide be applied, if possible, to the Gatling, I continued working with the idea of getting a form of packing-box for cartridges as originally put up, which should answer as feed-cases for the guns named, together with the Lowell, and at the same time be suitable for cartridges put up for general use with the service rifle.

In working up any such plan it was evident that a box costing more than that now made at Frankford Arsenal was inadmissible. Paper was therefore resorted to. The use of a paper box for the Gardner gun necessitates a perfectly smooth top when the cartridges are exposed, which it is impossible to get with the Frankford system of tearing the box open with a string. Recourse was therefore had to a box such as is now used by private manufacturers of ammunition—the Winchester Repeating Arms Company, New Haven, Conn.; the Union Metallic Cartridge Company, Bridgeport, Conn.; and the United States Cartridge Company of Lowell, Mass. The latter, being materially stronger and also somewhat wider than the others, was selected as the basis of the work.

The construction of the feed-guide of the Gardner gun is such that a space of about one-third of an inch is required between the rows of cartridges. It was therefore necessary to remove the spiral form of packing—Frasier's patent—from the box and insert another more like the Frankford, and which would allow the cartridges to be easily pulled from the box. I therefore took the packing from half a dozen Frankford boxes, placed the longitudinal partitions side by side (Fig. 1, Plate III) to get the requisite thickness between the rows of cartridges, and doubled the thickness of the cross partitions to prevent the wearing and deformation of heads of cartridges which is observed on those which have undergone rough transportation. This led at once to the use of a strip of thin board for the longitudinal partition (Fig. 2, Plate III) and of materially heavier pasteboard than that now used for the cross partitions.

On submitting this to the Pratt & Whitney Company for use with the Gardner gun it was greatly liked as being much more simple than the feed-cases they had already tried. In addition, it at once increased the capacity of the limber-chest to 5,400 rounds. One objection, however, was raised by the assistant superintendent, Mr. Parkhurst, who feared that when the cover was removed to insert the cartridge-heads in the guide, if the gun were at a high elevation, necessitating a corresponding inclination of the feed-case, some of the cartridges would fall out on the ground. To meet this, I proposed that the cover, on being removed, be turned upside down and held against the cartridge-heads, letting them slide along it as they entered the feed-guide. Mr. Parkhurst, however, proposed to put a sliding cover inside the box (Fig. 3, Plate III); this being done, gave such good results that it was favorably recommended by me to the commanding officer National Armory, who authorized its adoption for the Gardner guns then being made for the United States, the inspection of which I was conducting.

While good for the machine-gun this did not meet my expectations, in that it required an auxiliary cover, which was unnecessary for a box in which the great mass of cartridges to be packed are intended for use with the rifle and carbine.

I therefore returned to the idea of tearing out the end of the box cover by means of a muslin strip (Fig. 4, Plate III) in the manner indicated in the report previously referred to, omitting the inner cover and letting the outside cover slide over the cartridges, as it would be compelled to

by the central rib of the feed-guide. This proved exceedingly satisfactory, giving a simple form of box which can be made in quantity for about one cent each. The end which is torn out by the muslin is only held by the wrapping, the pasteboard being a separate piece. It no longer being necessary to preserve the feed-cases, some method of packing in the limber-chest (Plate IV) which would insure the non-shifting of the remaining cartridges, a portion only having been fired, was next to be devised. On calling the attention of the company to this Mr. Parkhurst proposed the following simple arrangement, which was adopted: The inner sides of the drawers of the limber-chest were grooved as shown in Plate V, the grooves being a distance apart slightly greater than the thickness of the feed-case. The length of the cases being almost exactly four times their thickness, they may be boxed off either horizontally or vertically by means of the movable partition accompanying each drawer. The whole makes a very compact packing, is simple, cheap, and requiring no preservation of feed-cases is exceedingly convenient.

Steps were next taken to adapt the whole system of feeding, packing, &c., to the Gatling, but owing to its being a very much more rapid firing gun than the Gardner and to the fact that cartridges can only be fed to it in a single row, the results were not at first as satisfactory as was to be desired.

A cartridge-guide similar in principle to the Gardner, but having a single groove for the cartridges, was prepared for trial with the feed-case last mentioned, but it was soon made evident that the combination would not answer for two reasons: 1. The guide could not be kept full because of the rapidity with which the gun could be fired, but 10 cartridges, or one row of the box, being entered at a time, and when once emptied the first cartridge from a new box falling irregularly would be caught and the motion of the gun checked. 2. After entering the first row of cartridges in the guide the sudden pulling away of the box to leave them there threw the cartridges in the other row, by their inertia, from the box to the ground.

Several single guides were then made with the view of filling them when not on the gun, and changing them, as is now done with the tin feed-case, the advantage of the former being that seven or eight could be filled in the time required for one of the latter, while preserving the method of packing. The firing, however, was not continuous as desired, and the single-grooved guide was definitely abandoned. A double-grooved guide was then made similar to the Gardner, except that the two grooves terminated in a tapering mouth-piece for the hopper of the gun. Trials showed no certainty whatever of the two rows of cartridges getting through the tapered mouth without binding, and the method was dropped.

The services of Mr. L. F. Bruce, of this armory, were then placed at my disposal, and it is to his ability, inventive skill, and unwearied persistence that I am indebted for the most perfect feed-guide ever proposed for the Gatling or any other machine gun which requires that the cartridges be fed to it in a single row. Several attempts were made with a vibrator or pendulum pivoted at the upper end of the guide, which alternately swung across the two rows, being actuated by the falling cartridges.

These attempts were still unsatisfactory, when Mr. Bruce proposed to pivot the double guide itself to a plate connected with a single guide entering the hopper of the gun, so that its grooves might be brought successively in line with the single guide. From this time success was

assured. Fig. 1, Plate XIX, shows a front view (section at bottom), Fig. 2 a side, and Fig. 3 a rear view; the Plate J, Fig. 2, having been removed, which covers the spring and spindle K, by means of which the double guide is so held that either of its grooves may be in line with that of the single guide. A, Figs. 1, 2, and 3, is the single guide, its upper portion being a flat plate to which the double guide B is pivoted by the screw C, as shown in section in Fig. 4, its lower end being fitted with a mouth-piece, D, for the hopper of the gun. The double guide is governed in its motion by the inclined planes E and F, which enter slots G at its lower end. These inclines have also another function, as explained further on. A projection, H, Fig. 3, on the rear of the double guide, entering the recess I, cut in the plate of the single guide, limits the lateral motion of the former, so that either of its grooves may be brought in line with that of the latter. The spring and spindle serve to hold it in either position.

The operation of this guide is as follows: Having been placed in the gun-hopper and securely fastened by the clamp L, it is filled with cartridges direct from the boxes in which they are proposed to be originally packed. On commencing the firing all cartridges in the long row begin running down; as soon as the last cartridge in that row of the double guide has entered the single guide, the weight of the column of cartridges in the other row of the double guide acting on the inclined plane F deflects the guide so as to bring this row in line with the single guide. Should the weight of the column of cartridges be insufficient, the pressure on this column resulting from the entering of additional boxes of cartridges produces the desired effect. As it sometimes happened that the guide became entirely empty, when the first cartridge down (being held by the head with the bullet end much depressed), was liable to jam and check the motion of the gun, Mr. Bruce proposed to put in a straightener at the bottom to correct its position before passing through to the carrier.

This, shown in section, Fig. 1, in elevation, Fig. 5, and in plan, Fig. 6, Plate XIX, is simply a catch, M, hinged to the side of the mouth of the guide. The screw N may be turned in or out, decreasing or increasing the ease with which the catch yields to the weight of cartridges required to operate it. It may therefore be so adjusted as to hold a single cartridge only. When the column of cartridges presses from above it turns about its hinge and the cartridges fall through to the carrier of the gun. In connection with the catch a roller, O, Figs. 1 and 2, secured by three small screws, was found necessary. This guide not being entirely satisfactory because of its small capacity, another one, Plate XII, was made having the upper guide of sufficient length to hold 30 cartridges in each groove. This afforded the means of filling with three of the ordinary boxes of 20 each. The lower or single guide was reduced to a minimum with the view of eliminating the distance through which the cartridges had to fall after the upper guide shifted, and which sometimes made the firing somewhat intermittent, and also with the view of keeping the total length down to that of the present tin feed-case, so that it could be carried in the limber-chest as is now done.

The cartridge straightener at the bottom of the mouth-piece was replaced by a simple fluted roll or wheel, A, which, turning by the weight of the cartridge, passed the latter through to the shelf B, by which it was shunted off into the carrier of the gun. In order to remove the guide from the gun at any time without permitting the cartridges to fall from it to the ground, the roll may be locked by pressing down the slide C until it enters one of its flutes. The slide is prevented from losing

out by the spring and pin D, the latter of which enters a recess in the fender E, in which the slide works.

A simple and better form of clamp for securing the guide to the gun was also devised. The inner end of the screw F works in an under cut in the shoe G. Owing to the oblong hole H admitting of motion of the pin connecting the shoe with the mouth-piece of the guide, the shoe has a motion of translation as well as rotation, and therefore comes to a firm bearing against the front of the hopper of the gun. This guide, in combination with the paper box, has proved very successful—though it is perhaps too much to say that it is absolutely perfect—giving for the first time a continuous fire with the Gatling gun, and thereby making it the equal if not the superior of any machine gun in existence.

We are now enabled to carry 5,400 rounds of ammunition in the limber-chest of the narrow-track (44″) carriage furnished by the Pratt & Whitney Company, of Hartford, Conn., makers of the Gardner gun, and 4,860 in that of the Colt's Patent Fire Arms Manufacturing Company, of Hartford, Conn., makers of the Gatling gun, instead of 2,000 by the system in service; to diminish the weight of feed-cases required for the latter 130 pounds and the expense by nearly $100.

In addition, the cartridges as put up at an arsenal for use with the service rifle and carbine are always directly available for use with the Gardner, Gatling, and Lowell guns.

The carriages for the latter two guns as made at the United States Watervliet Arsenal have a track of 60 inches, giving much wider limber-chests (Plates VIII and XIII), and in addition the Gatling has two and the Lowell four small chests parallel to the gun. The proportionate increase of carrying capacity is therefore vastly greater.

Attention was next turned to the "Lowell battery gun," which also requires that cartridges be fed to it in a single row. Under the present system the cartridges are first inserted in tin guides (Figs. 4–6, Plate XV) holding 20 each, which are in turn inserted in the feed-guide proper (Figs. 1–3, Plate XV) when the gun is to be fired. This tedious and puttering method necessitates a still more puttering arrangement of the carriage and limber-chests for transportation of the ammunition. The tin guides having been filled, they are so packed (Plate XIV) that the cartridges are suspended as it were by their heads, the bullets partly entering holes in boards arranged to separate the various tiers. To so hold the guide and adjust 20 swinging cartridges that they shall be over their respective holes before being lowered to position requires both skill and unremitting attention, the cartridges persistently getting in the wrong ones; and when this operation is repeated 500 times to fill the ammunition boxes which accompany a single gun, sweetness of temper far beyond what ordinarily falls to the lot of mortals is an added concomitant. In addition, when a portion of the cartridges have been fired from any box nothing prevents the tipping over and jolting about of the remaining ones.

A double guide (Plate XVIII) differing in no respect from that for the Gatling except in the part which enters the hopper, which is the same as at present in use, was next prepared. Trials with this guide showed that the gun could easily be supplied with cartridges so as to give a continuous fire.

## CONCLUSIONS.

It now affords me the utmost pleasure and satisfaction to announce as an accomplished fact one of the most important simplifications of ordnance material made for many years, viz:

One limber for all machine guns in service, the gun-carriages differ-

ing only in the mountings for the various guns, with even this feature left open for future consideration; a double flanged feed-guide for each gun; the use as a feed-case of a paper box holding 20 cartridges as put up at an arsenal for the rifle and carbine; the total abolition of all special appliances for feeding, such as the Gatling tin feed-case (Plate IX), the Lowell tin guide (Plate XV), &c.; the more than doubling the cartridge-carrying capacity (12,160 instead of 5,280 rounds) of the Gatling field carriage as made at the United States Watervliet arsenal; increasing that of the Lowell from 10,000 to 14,800, and the Gardner narrow-track carriage from 3,000 to 5,400, together with diminished cost of construction of the carriages; of the special appliances for the guns and their useless weight, the cost being for the 132 feed-cases accompanying the Gatling field carriage $264 and the weight about 340 lbs.

## RECOMMENDATIONS.

In view of the foregoing facts I have the honor to recommend as follows:

### *I.—Limber and limber-chest.*

To be those of the Lowell [Plate XVI], as made at the United States Watervliet Arsenal, the drawers of the chest [Plate XVII], to be without covers and to have handles like that of the upper middle chest, and to have the following dimensions:

Interior measurement, 20″.75 × 12″.5 × 7″.

Sides, ends, and bottoms, 0″.87 thick.

Capacity of each drawer 1,480, and of chest (6 drawers) 8,880 cartridges.

In addition, two drawers to be carried as at present on each side of the gun, or, 5,920 cartridges. Total number of rounds accompanying each gun, 14,800.

### *II.—The feed-guide.*

For the Gatling, as shown in Plate XII*.

For the Lowell, as shown in Plate XVIII.

For the Gardner, same as at present, except that center rib should be reduced (Plate VII) to that of Gatling and Lowell to admit of use of the same paper feed-case.

### *III.—The feed-case.*

Paper box as shown in Plates VII, XII, and XVIII. Exterior dimensions: body, 6″.1 × 2″ × 1″.3; cover, 6″.2 × 1″.3 × 1″.4; when filled, 6″.2 × 2″.65 × 1″.4. One end of cover to be a separate piece of pasteboard to admit of being easily torn out by muslin strip pasted on its inner side, and the partitions to be glued to bottom of box. *This box also to be used for packing all cartridges for use with the rifle and carbine.*

## ALTERNATIVE RECOMMENDATIONS.

Should it be thought desirable to afford a comparative trial in the service of the proposed system and that now in use, with the same gun, the following recommendations are made:

I. That the Lowell carriage be issued without change, the four am-

*The guide herewith submitted is the result of frequent trials and alterations. In a new one the small plate at the back would be cast solid with the main plate, the mouth-piece would be brazed to the single guide, and the channel in that guide would be straight instead of inclining to the right, admitting of a straight-toothed wheel. This inclination was given for another purpose before the wheel was introduced.

munition boxes, capacity 1,000 rounds each, on the gun-carriage being filled as at present, and the six in the limber-chest, capacity 1,120 each, packed as proposed for use with the double-flanged guide.

II. That the Gatling gun-carriage be issued without change, the small chests, capacity 720 rounds each, parallel to the gun, being filled with the ordinary tin feed-case as at present. That the limber-chest (Plate X) have the interior removed and be partitioned like the Lowell, except that the horizontal partition be but 0''.87 thick, and that the drawers (Plate XI) have the following dimensions, owing to the smaller size of chest:

Interior measurement, 20''.25 × 11''. 3 × 7''; sides and ends, 0''.87, and bottom, 0''.75 thick. Capacity of each drawer 1,280, and of chest 7,680 rounds.

### AUXILIARY RECOMMENDATIONS.

As 25 Gatling guns are now being made at the Colt's Armory, Hartford, Conn., adapted to the experimental cartridge (500-gr. bullet) for which special feed-cases will be necessary, it is recommended that 25 double-flanged cartridge-guides be made at this post for trial with them; also, if the carriages have not yet been made that the Lowell limber, Watervliet Arsenal pattern, with drawers of the size first recommended, be issued with them, the gun-carriage chests being constructed as at present or adapted to the proposed system as may be preferred. The various feed-guides and cases, except those of the present systems, are submitted herewith. Appended will be found a list of the accompanying plates.

Very respectfully, your obedient servant,

JOHN E. GREER,
*Captain of Ordnance, U. S. A.*

To the COMMANDING OFFICER NATIONAL ARMORY.

NATIONAL ARMORY, *June* 16, 1881.

Since the above was written a change in the form of the guide, by which the wheel is placed to the right so as to roll the cartridges in the direction the carrier is rotating, has been proposed. This, while necessitating a slight change in the hopper of the gun, seems especially worthy of trial. If found desirable the change could be made in the new model gun, the guide herewith submitted being issued for the guns now in service.

J. E. G.

## LIST OF PLATES.

Plate XII. Gatling feed-guide and case, proposed system.
Plate XIII. Lowell limber-chest, Watervliet Arsenal pattern, rear view, present system.
Plate XIV. Lowell limber-chest ammunition boxes, showing method of packing, present system.
Plate XV. Lowell feed-guide and case, present system.
Plate XVI. Lowell limber-chest, rear view, proposed system *for all machine guns.*
Plate XVII. Lowell limber-chest drawers, showing proposed method of packing, &c., for *all guns.*
Plate XVIII. Lowell feed-guide and case, proposed system.
Plate XIX. Gatling feed-guide No. 1, experimental.
Plate XX. Showing method of filling feed-guide direct from case.

[*First indorsement.*]

NATIONAL ARMORY, *June* 16, 1881.

Respectfully forwarded to the Chief of Ordnance.

The details of this plan for harmonizing and simplifying the several methods of feeding the machine guns now in service has been worked out with much pains by Captain Greer, assisted by Mr. L. F. Bruce, a workman of this armory, and I think it meets a decided want of the service.

I would suggest that it be examined and tried by a board of officers with a view to adoption.

J. G. BENTON,
*Colonel of Ordnance, Commanding.*

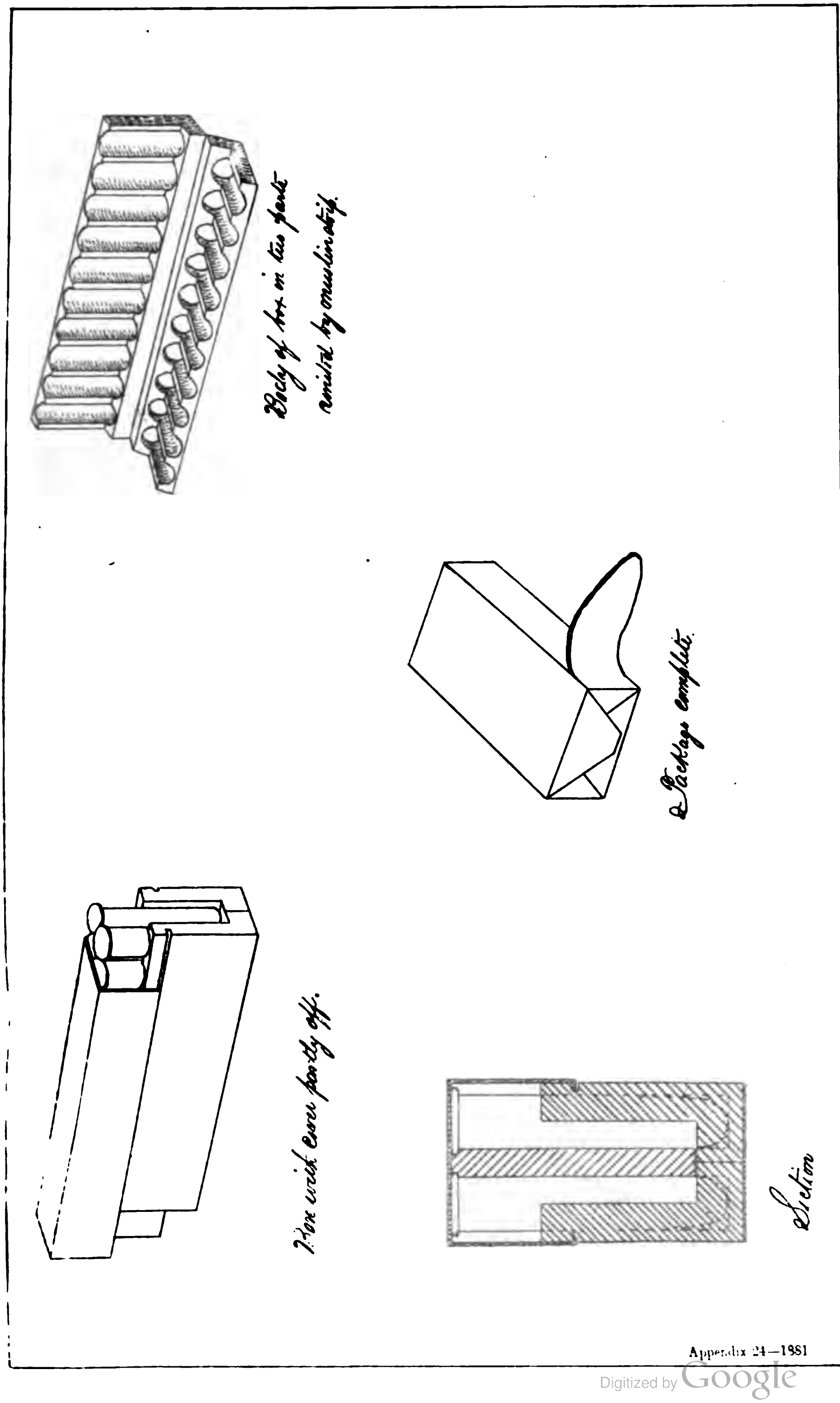
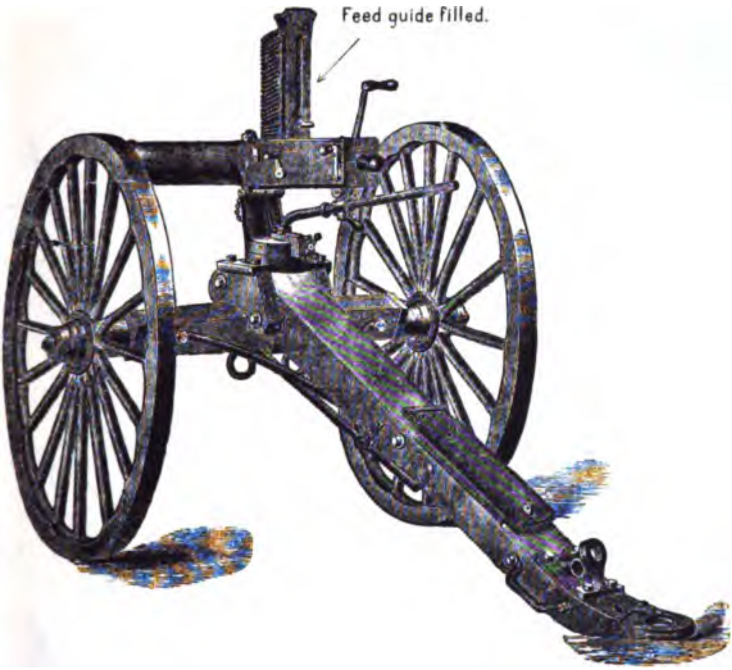

Body of box in two parts united by muslin strip.
Package complete.
Box with cover partly off.
Section

Fig. 1.




GUN MOUNTED ON ARMY CARRIAGE.

Fig. 2.


GUN MOUNTED ON TRIPOD.

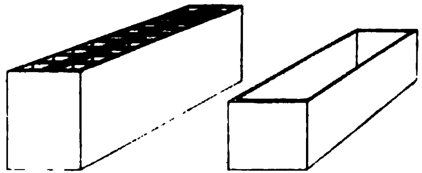


Fig. 1.

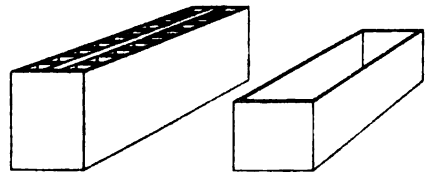


Fig. 2.

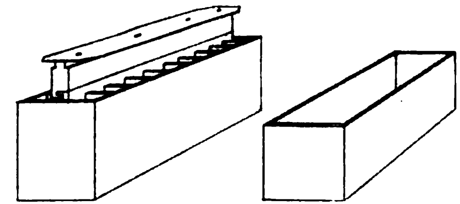


Fig. 3.

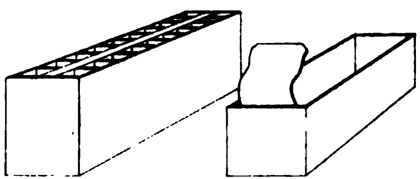


Fig. 4.

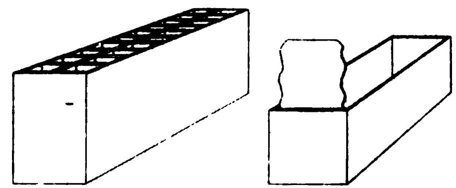
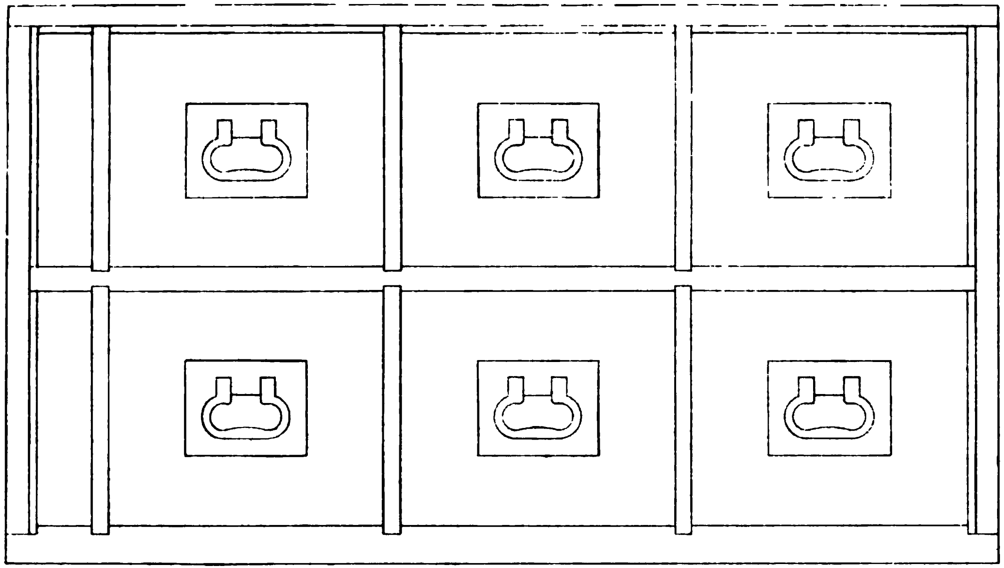


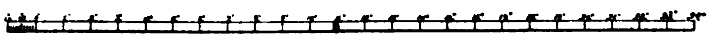
Fig. 5.

# MACHINE GUNS.

## FEED-CASES.—VARIOUS PATTERNS.

Fig. 1. Experimental. Fig. 3. Gardner.
Fig. 2. Experimental. Fig. 4. Experimental.
Fig. 5. Proposed for all Machine Guns.





# MACHINE GUNS.

## GARDNER GUN LIMBER-CHEST.

Narrow Track Carriage.

REAR VIEW; PRESENT SYSTEM.

Capacity of Chest, - - - 5400 cartridges.

# MACHINE GUNS.

## GARDNER GUN LIMBER-CHEST DRAWER,

SHOWING

### Method of Packing Ammunition.

Fig. 1. Plan.
Fig. 2. Longitudinal section.
Fig. 3. Cross section.
A. Movable partition.

Capacity of Drawer 900 cartridges
Capacity of Chest 5400 cartridges

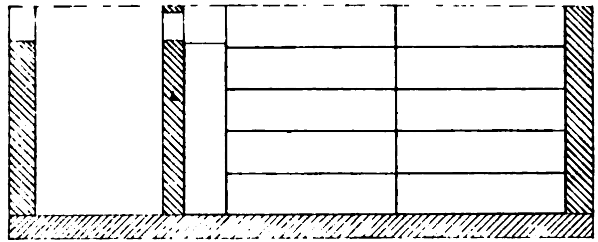


Fig. 2.

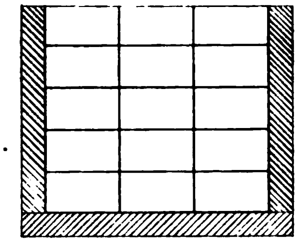


Fig. 3.

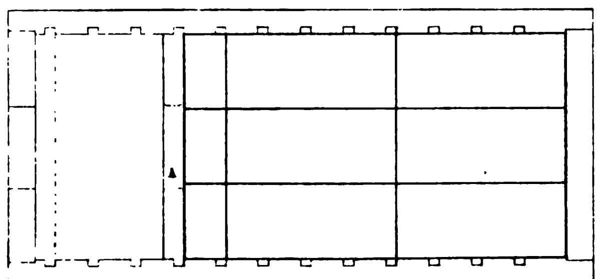
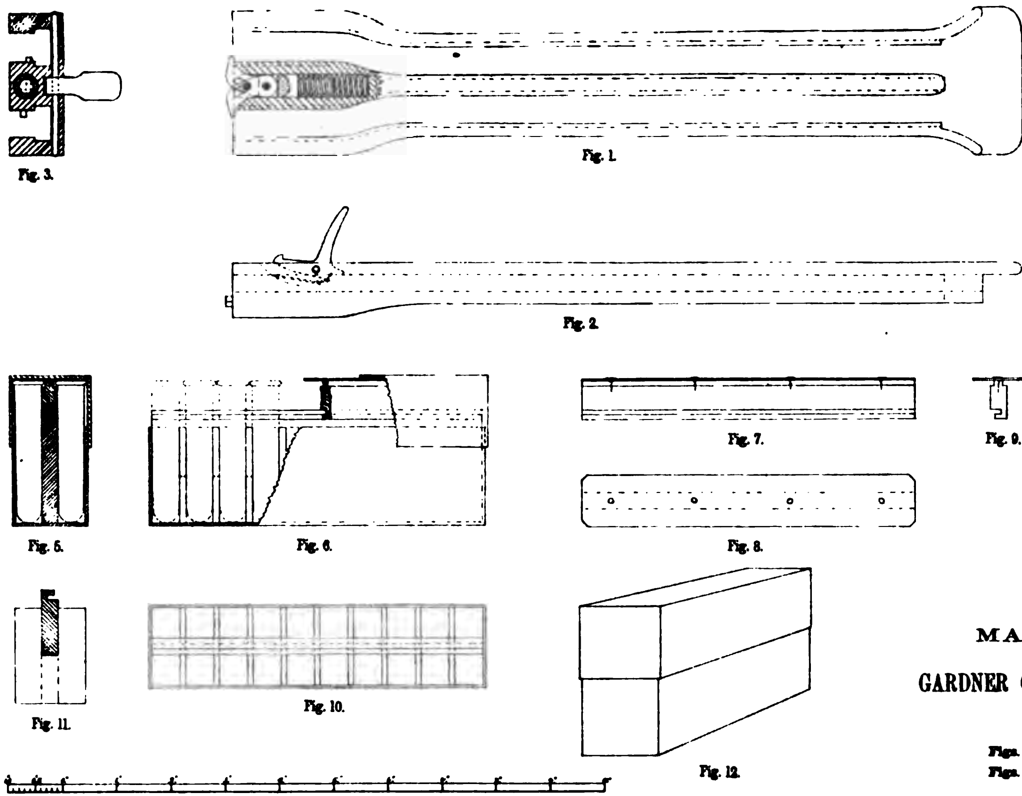




Fig. 1.




# MACHINE GUNS.

## GARDNER GUN FEED-GUIDE AND CASE,

PRESENT SYSTEM.

Figs. 1—4. - - - - Feed-guide.
Figs. 5—12. - - - - Feed-case.

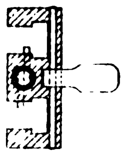


Fig. 3.

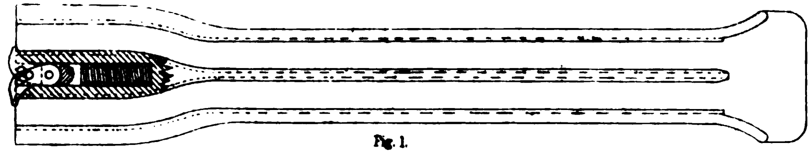


Fig. 1.

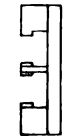


Fig. 4.

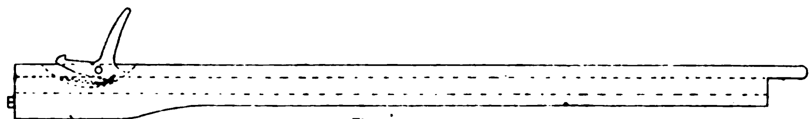


Fig. 2.

Fig. 5.

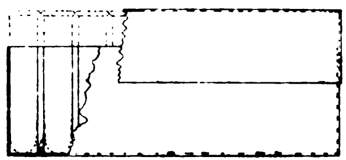


Fig. 6.

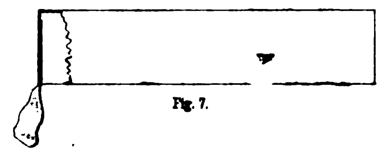


Fig. 7.

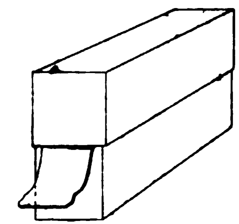


Fig. 11.

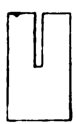


Fig. 10.

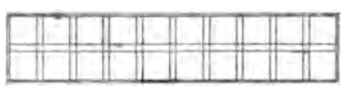


Fig. 8.

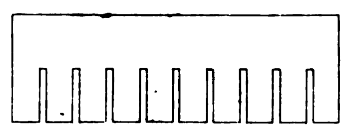


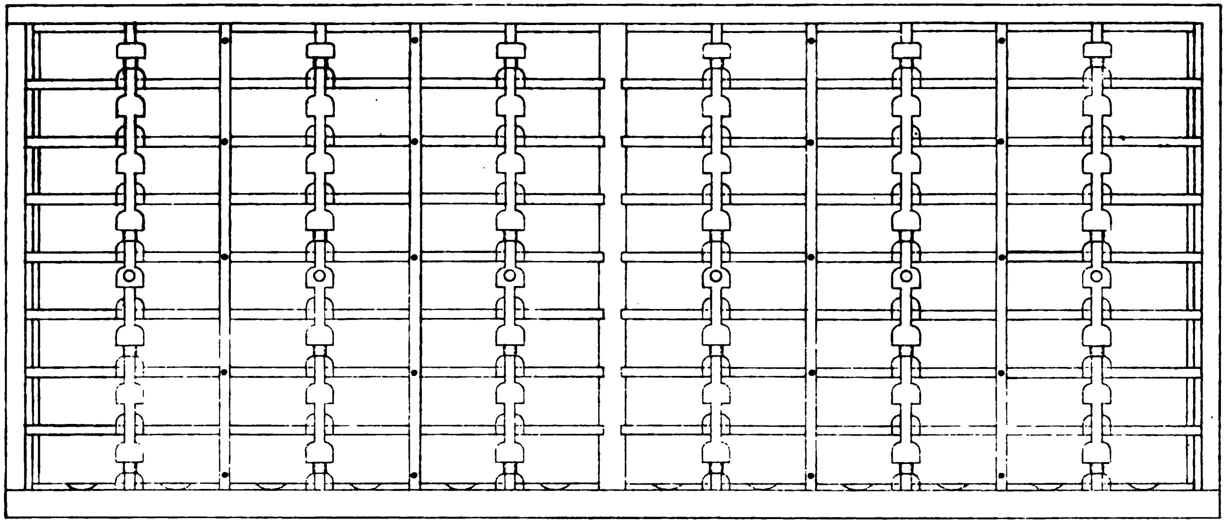
Fig. 9.

MACHINE GUNS.

GARDNER GUN FEED-GUIDE AND CASE,

PROPOSED SYSTEM.

Figs. 1—4. . . . . Feed-guide.
Figs. 5—11. . . . . Feed-case.



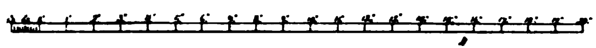
# MACHINE GUNS.

## GATLING GUN LIMBER-CHEST,

Watervliet Arsenal Pattern.

REAR VIEW; PRESENT SYSTEM.

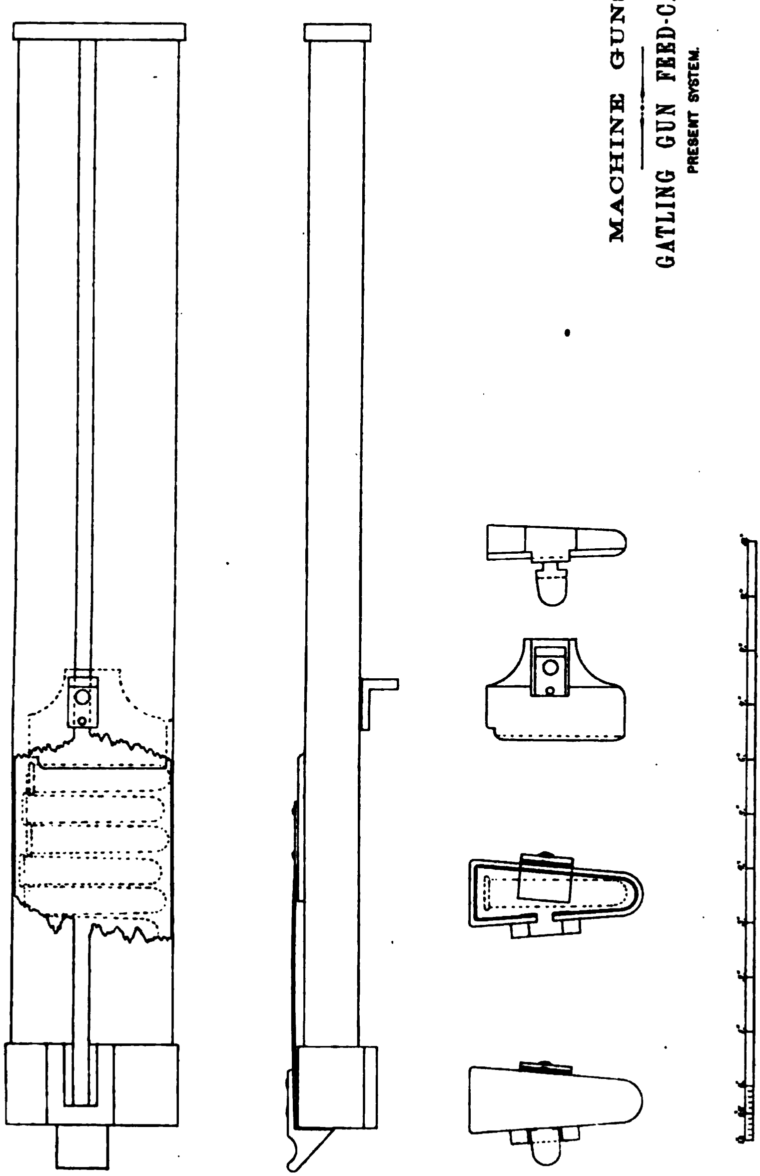
Capacity of Chest, - - - 3840 cartridges.

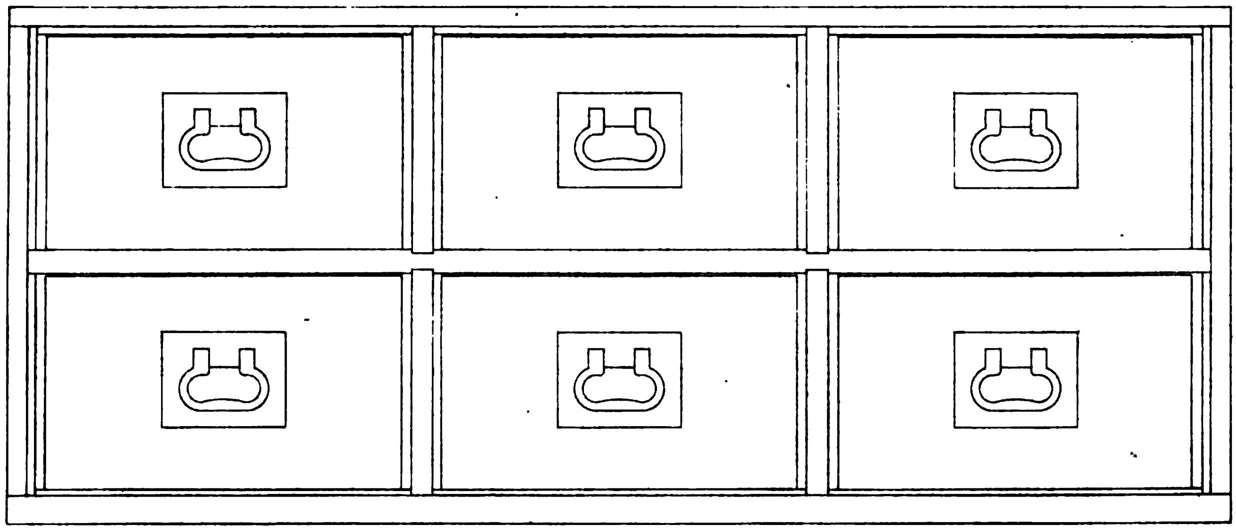


MACHINE GUNS.

GATLING GUN FEED-CASE,

PRESENT SYSTEM.





MACHINE GUNS.

GATLING GUN LIMBER-CHEST,

REAR VIEW; PROPOSED SYSTEM.

Capacity of Chest, - - - 7680 cartridges.

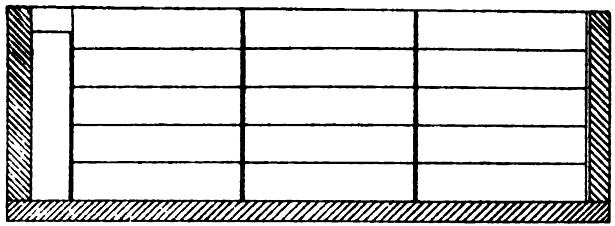


Fig. 2.

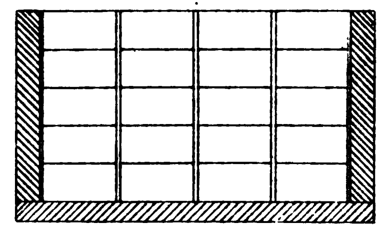


Fig. 3.

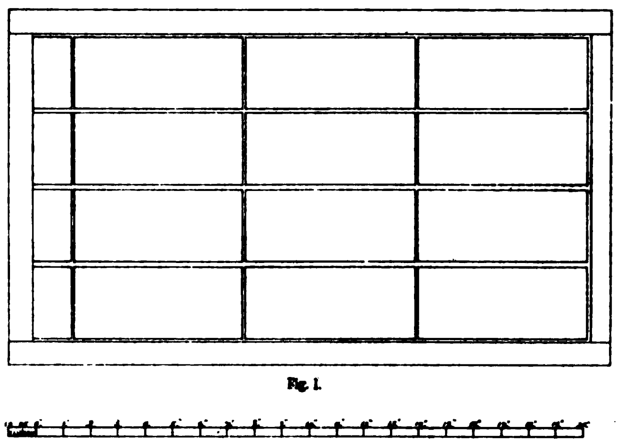


Fig. 1.

# MACHINE GUNS.

## GATLING GUN LIMBER-CHEST DRAWER,

SHOWING

### Proposed Method of Packing Ammunition.

Fig. 1. Plan. Fig. 2. Longitudinal section.
Fig. 3. Cross section.

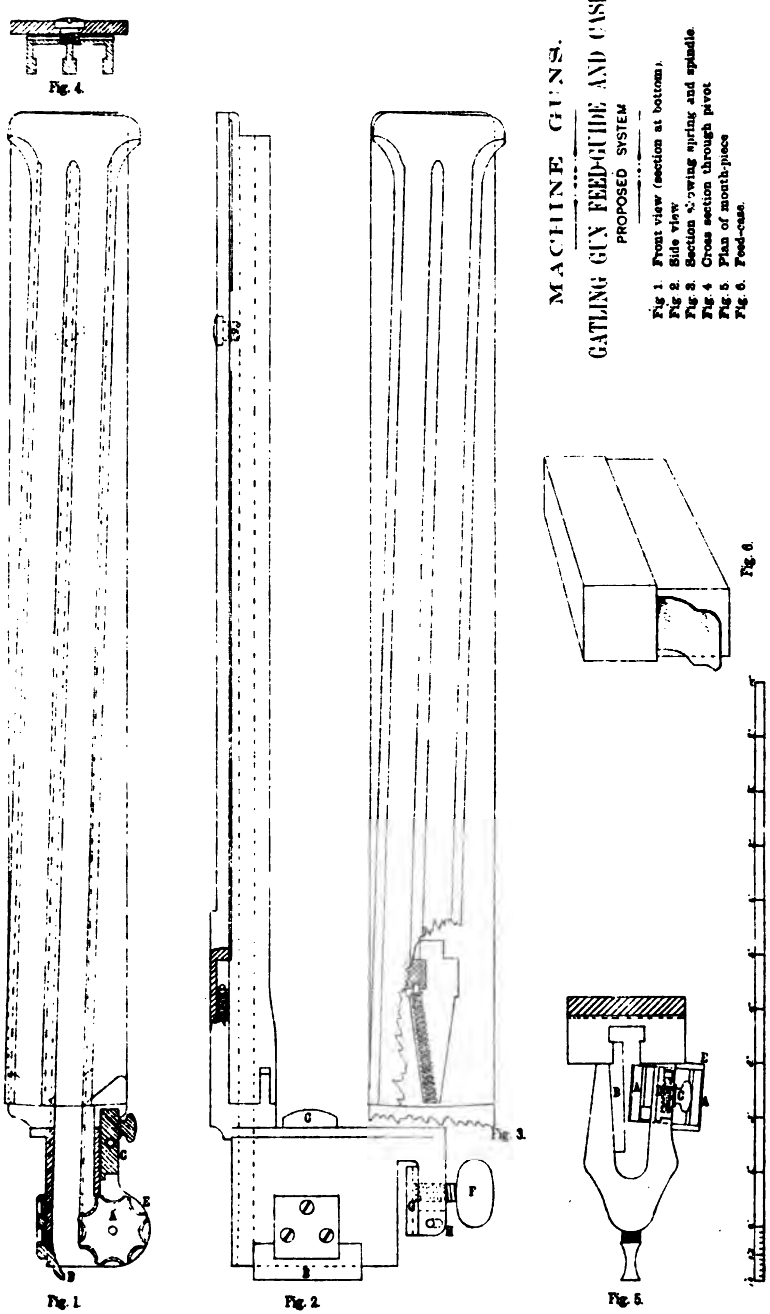
Capacity of Drawer, 1960 cartridges.
Capacity of Chest, 7680 cartridges.

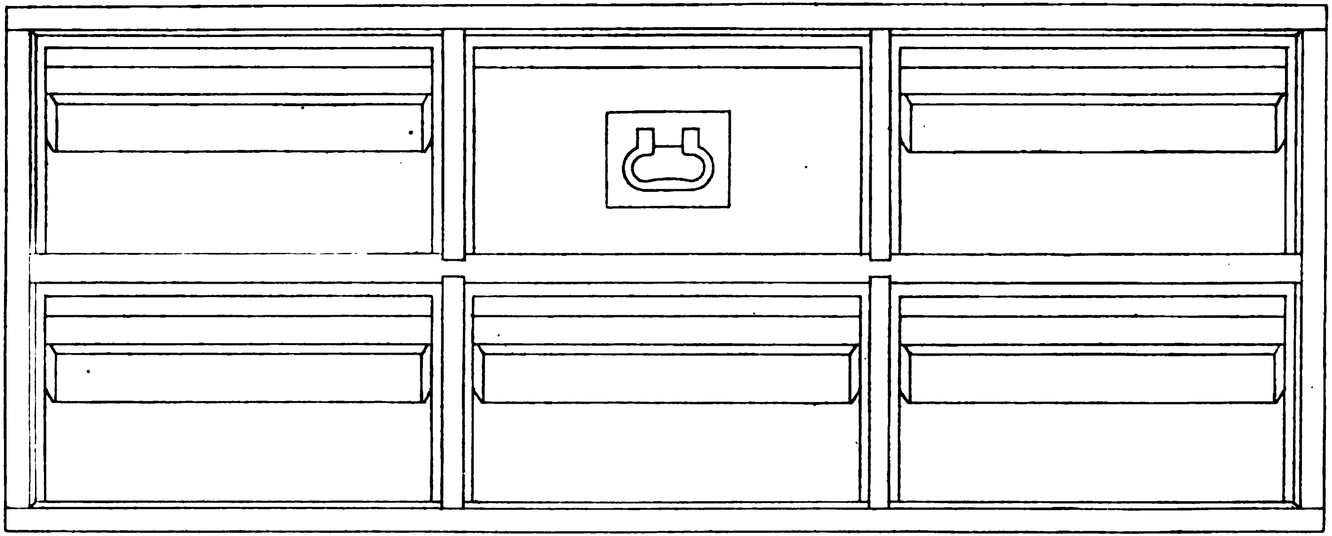
# MACHINE GUNS.

## GATLING GUN FEED-GUIDE AND CASE,

PROPOSED SYSTEM

Fig 1. Front view (section at bottom).
Fig 2. Side view
Fig 3. Section showing spring and spindle.
Fig 4. Cross section through pivot
Fig 5. Plan of mouth-piece
Fig 6. Feed-case.





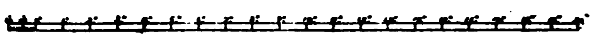
# MACHINE GUNS.

## LOWELL GUN LIMBER-CHEST,

**Watervliet Arsenal Pattern.**

REAR VIEW; PRESENT SYSTEM.

Capacity of Chest, - - - 6000 cartridges.



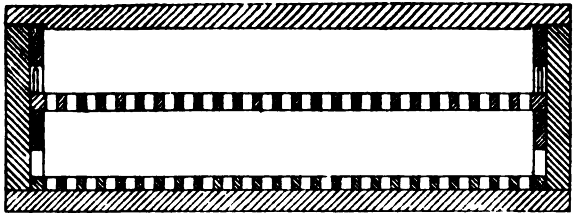


Fig. 2.

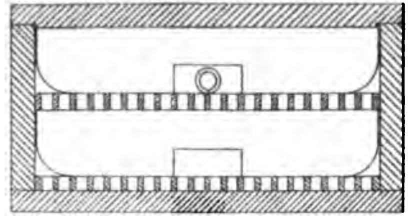


Fig. 3.

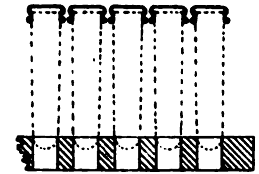


Fig. 4.

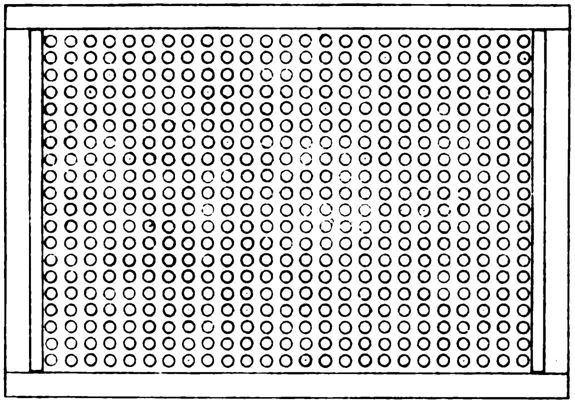
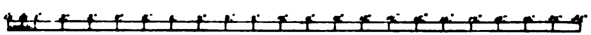


Fig. 1.



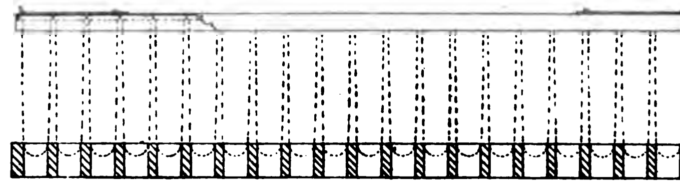


Fig. 5.

# MACHINE GUNS.

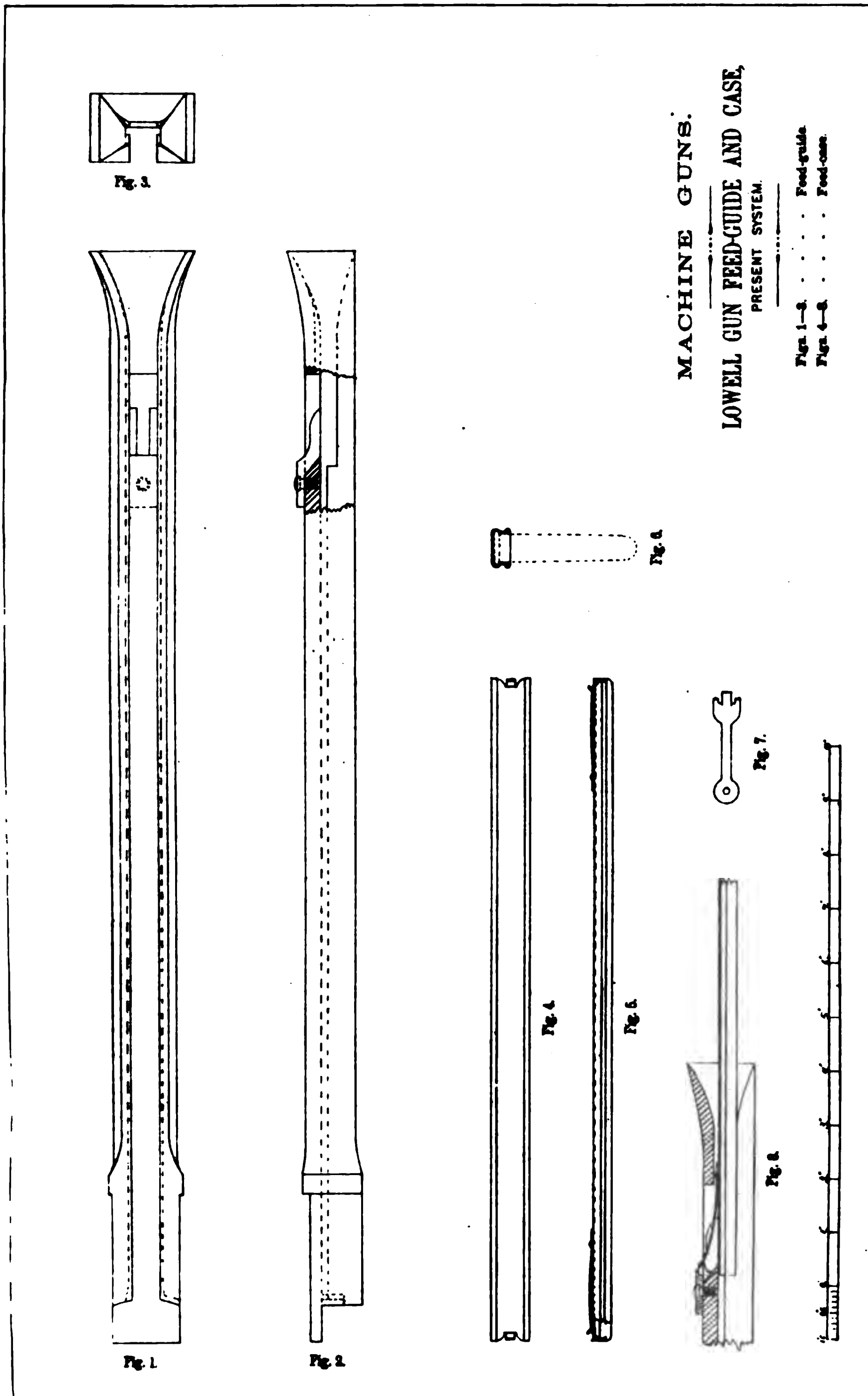
## LOWELL GUN LIMBER-CHEST BOX,

SHOWING

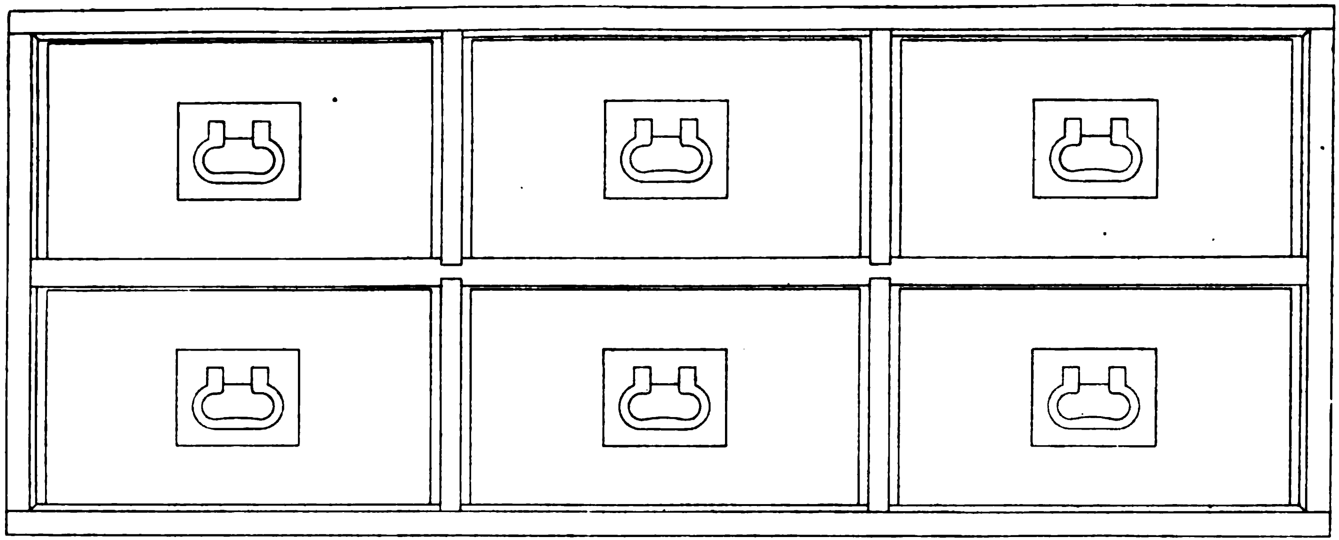
*Method of Packing Ammunition; present system.*

Figs. 1—3. Plan and sections of box.
Figs. 4 and 5. Sections showing position of cartridges in box.

Capacity of Box, 1000 cartridges.
Capacity of Chest, 6000 cartridges.




Appendix 34 —1881.



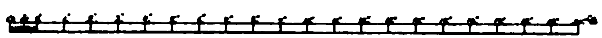
MACHINE GUNS.

LOWELL GUN LIMBER-CHEST.

REAR VIEW.

Proposed for all Machine Guns.

Capacity of Chest, . . . 8880 cartridges.



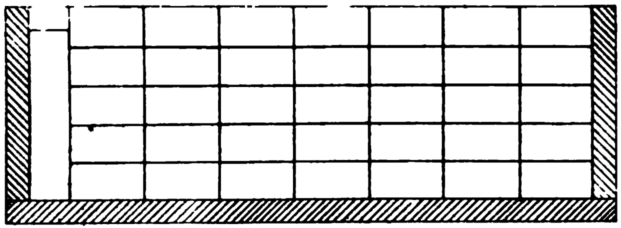


Fig. 2.

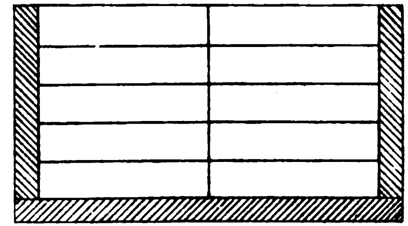


Fig. 3.

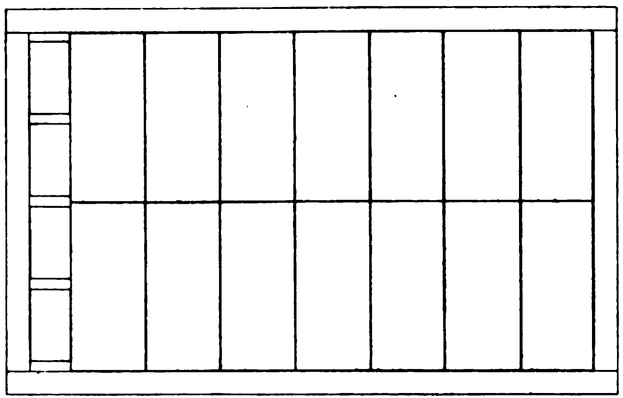


Fig. 1.

# MACHINE GUNS.

## LOWELL GUN LIMBER-CHEST DRAWER,

SHOWING

### Proposed Method of Packing Ammunition

FOR ALL MACHINE GUNS.

Fig. 1. Plan. Fig. 2. Longitudinal section.
Fig. 3. Cross section.

Capacity of Drawer, 1480 cartridges.
Capacity of Chest, 8880 cartridges.

# MACHINE GUNS.

## LOWELL GUN FEED-GUIDE AND CASE.

PROPOSED SYSTEM.

Figs. 1—6. . . . . . Feed-guide.
Figs. 7. . . . . . Feed-case.

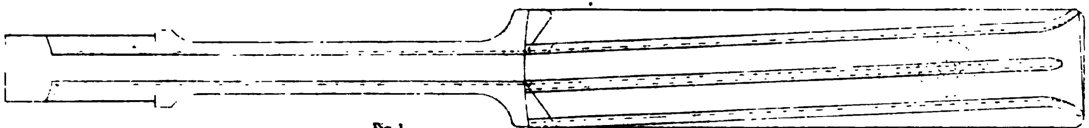


Fig. 1.

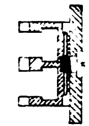


Fig. 4.

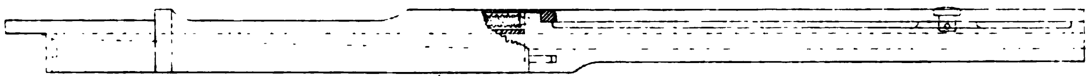


Fig. 2.

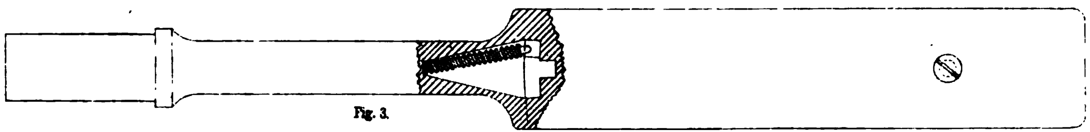
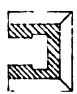


Fig. 3.

Fig. 5.



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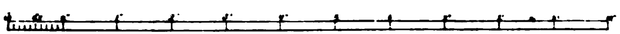


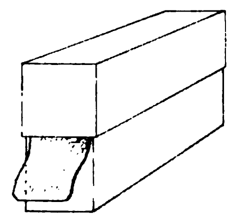


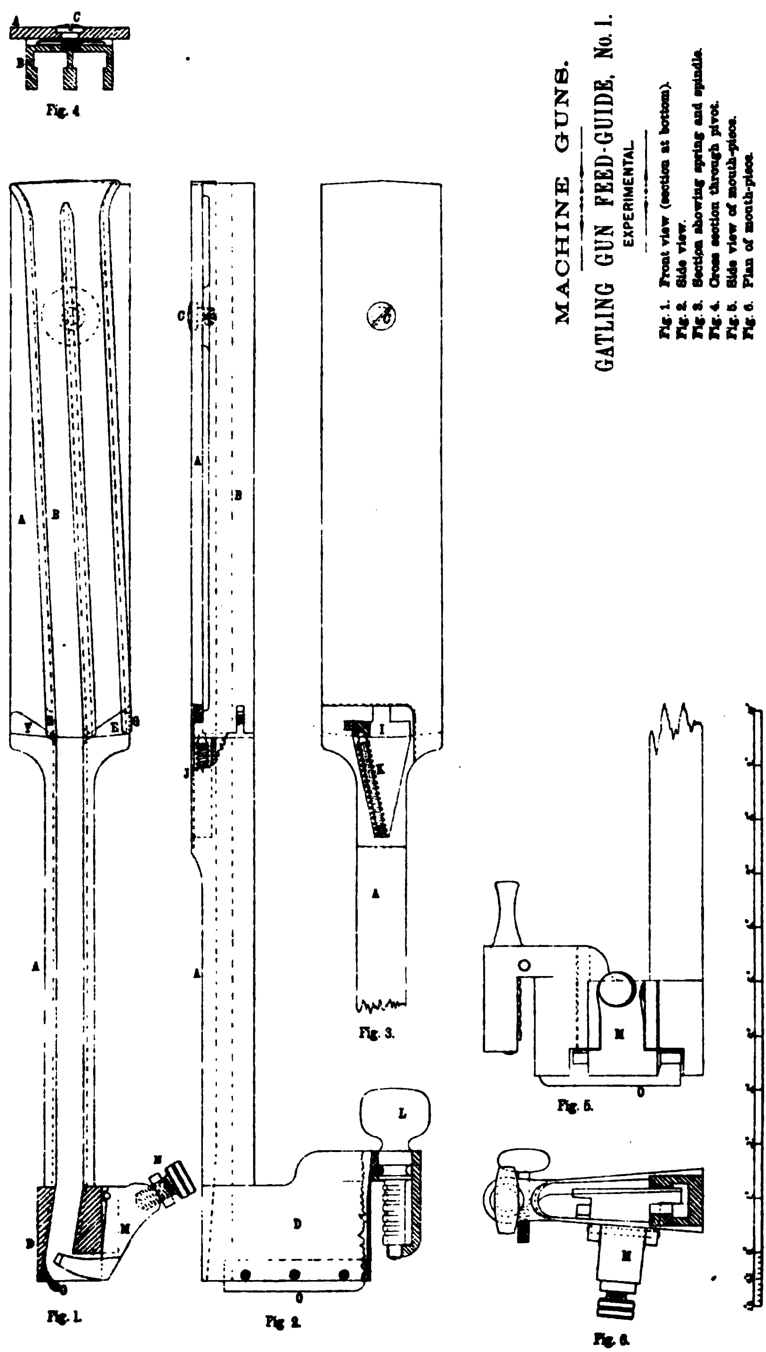
Fig. 7.

# MACHINE GUNS.

## GATLING GUN FEED-GUIDE, No. 1.

EXPERIMENTAL.

Fig. 1. Front view (section at bottom).
Fig. 2. Side view.
Fig. 3. Section showing spring and spindle.
Fig. 4. Cross section through pivot.
Fig. 5. Side view of mouth-piece.
Fig. 6. Plan of mouth-piece.



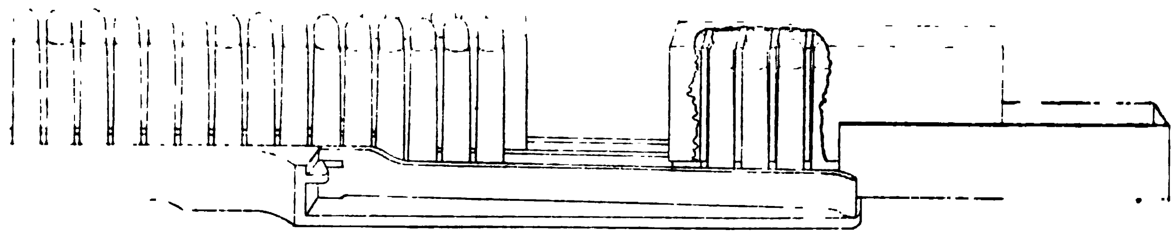


Fig 1.

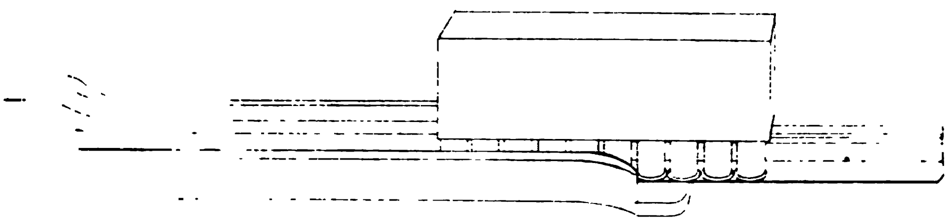


Fig 2.

MACHINE GUNS.

METHOD OF FILLING FEED GUIDE
DIRECT FROM CASE.

Fig 1. Lowell and Gatling proposed system.
Fig 2. Gardner present system.

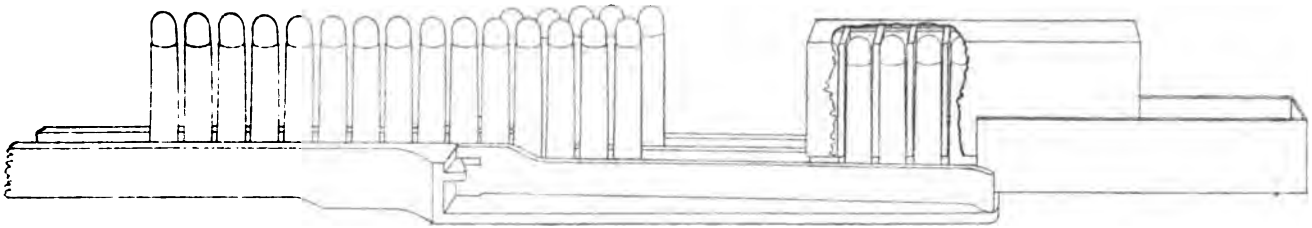


Fig. 1.

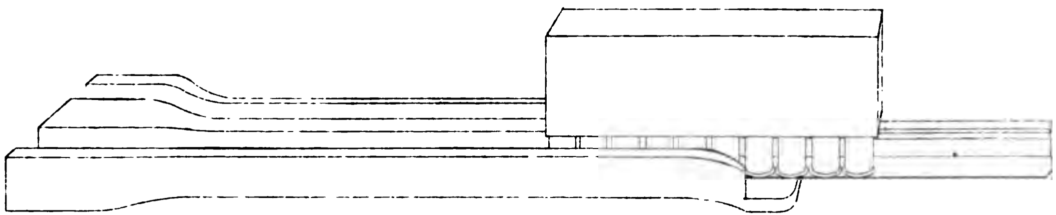


Fig. 2.

# MACHINE GUNS.

## METHOD OF FILLING FEED-GUIDE DIRECT FROM CASE.

Fig. 1. Lowell and Gatling, proposed system.
Fig. 2. Gardner; present system.

## APPENDIX 25.

### REPORT ON THE HUNT LIFE-SAVING PROJECTILE.

BY LIEUTENANT D. A. LYLE, ORDNANCE DEPARTMENT, U. S. A.

(Eight Plates.)



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### LIST OF PLATES.

### EXPLANATION.

*Plate I.*

FIGURE 1.—Side elevation of Hunt line-carrying projectile.
H. Head or point of shot.
R. Reinforce.
B.B. Body.
W.W. Wings.
G. Position of center of gravity of projectile with line.
I. Position of center of gravity of projectile empty (without line).
C. Center of figure of projectile.
L. Line.

FIGURE 2.—Longitudinal section of Hunt projectile, showing side elevation and partial section of coil of line.
H. Head.
L. Line.
P. Wooden plug.
W.W. Wings.

FIGURE 3.—Rear elevation of Hunt projectile, showing relative positions of wings.
B.B. Body.
P. Wooden plug.
L. Line.
W.W. Wings.

*Plate II.*

FIGURE 1.—Side elevation of Hunt's shore-can.
FIGURE 2.—Plan of top of shore-can with paper disk removed, showing coil of line in position for firing.
FIGURE 3.—Plan of bottom of shore-can, showing safety-ring.
FIGURE 4.—Longitudinal section of shore-can, showing side elevation and partial section of coil of line.

*Plate III.*

FIGURE 1.—Diagram showing the effect of a transverse wind upon the Hunt line and projectile. Velocity of wind, 15.34 miles per hour.
A.B. Line of fire.
A. Position of 3-inch Lyle gun "A."
C. Position of shore-can at moment of firing.
D. Position of shore-can after firing.
L. L. Position of line after firing.
P. Position of projectile after firing.
W.W. Direction of wind.

FIGURE 2.—Diagram showing relative positions of lines of fire in the comparative trials of October 23–25, 1880.
A.B. Line of fire for Lyle projectile.
C.D. Line of fire for Hunt projectile.
A. Position of 2.5-inch Lyle gun.
C. Position of 3-inch Lyle gun "A."
F. Position of faking-box for Lyle projectile.
H. Position of Hunt's shore-can and line.
EE. Wire from battery to guns.
G. Return wires which complete the galvanic circuit.

NOTE.—In Plates IV and V the planes of fire are projected upon the same vertical plane, or, in other words, the two planes are assumed to coincide, in order that the deviations and drifts may be measured from the same right line (*i. e.*, the common horizontal trace of the two planes) for purposes of direct graphical comparison.

*Plate IV.*

FIGURE 1.—Diagram showing the relative positions on the grounds of the Lyle and Hunt shot-lines in the "first set" of simultaneous firings, October 21, 1880.
A. Position of Lyle projectile after firing.

B. Position of Hunt projectile after firing.
C. Firing point.
C.D. Horizontal projection of lines of fire.
*a.a.a.* Position of Lyle line on the ground after firing.
*b.b.b.* Position of Hunt line on the ground after firing.
W.W. Direction of wind.

FIGURE 2.—Diagram showing the relative positions on the ground of the Lyle and Hunt shot-lines in the "second set" of simultaneous firings, October 21, 1880.
A. Position of Hunt projectile after firing.
B. Position of Lyle projectile after firing.
C. Firing point.
C.D. Horizontal projection of lines of fire.
*a.a.a.* Position of Lyle line on the ground after firing.
*b.b.b.* Position of Hunt line on the ground after firing.
W.W. Direction of wind.

*Plate V.*

FIGURE 1.—Diagram showing the relative positions on the ground of the Lyle and Hunt shot-lines in the "third set" of simultaneous firings, October 25, 1880.
A. Position of Lyle projectile after firing.
B. Position of Hunt projectile after firing.
C. Firing point.
C.D. Horizontal projection of lines of fire.
E. Position of Hunt shore-can after firing, 51 feet in front of firing point.
*a.a.a.* Position of Lyle line on the ground after firing.
*b.b.b.* Position of Hunt line on the ground after firing.
W.W. Direction of wind.

FIGURE 2.—Diagram showing the relative positions on the ground of the Lyle and Hunt shot-lines in the "fourth set" of simultaneous firings, October 25, 1880.
A. Position of Lyle projectile after firing.
B. Position of Hunt projectile after firing.
C. Firing point.
C.D. Horizontal projection of lines of fire.
*a.a.a.* Position of Lyle line on the ground after firing.
*b.b.b.* Position of Hunt line on the ground after firing.
W.W. Direction of wind.

*Plate VI.*

Diagram showing normal trajectory for an angle of projection of 25° and an initial velocity of 250 feet per second; also showing the action of the resistance of the air upon the Hunt projectile.

FIGURE 1.—Vertical projection of normal trajectory, showing abscissas and ordinates.
A.—Firing point, the origin of co-ordinates being taken at the center of the bore at the muzzle of the piece.
B. Point of fall.
A.B. Range.
C. Highest point of trajectory.
A.D. Line of projection.

FIGURE 2.—Vertical projection of normal trajectory.

A. Firing point.
B. Point of fall.
A.B. Range.
A.D. Line of projection.
H. Hunt projectile.
G. Center of gravity.
F. Center of figure.
T. Tangent to trajectory.
R. Resultant of the resistance of the air, whose line of direction passes through the center of figure.

NOTE.—The surface of the projectile exposed to the resistance of the air is included between the dotted lines parallel to the tangent, and R is the resultant of this resistance, which diminishes the velocity and range of the projectile and, as shown in the figure, tends to rotate the rear end of the projectile about its center of gravity—upward in the first case and downward in the second. This action of the resistance of the air produces the vertical oscillations observed in the projectile's flight.

*Plate VII.*

Diagrams of the Hunt and Lyle life-saving projectile, showing the action of lateral winds to produce a motion of rotation about the center of gravity.

FIGURE 1.—2.5-inch Lyle projectile.

G. Center of gravity.
C. Center of figure.
R. Resultant force of lateral wind.
C.F. Direction in which the force of the wind tends to rotate the projectile about the center of gravity.

FIGURE 2.—Diagram showing the relative directions in which the lateral forces of the wind and the weight of the projectile act.

C. Center.
L. Direction of wind.
W. Weight.

FIGURE 3.—3-inch Hunt projectile.

G. Center of gravity when full of line.
I. Center of gravity when empty.
C. Center of figure.
R. Resultant force of lateral wind.
C.D. Direction in which the force of the wind tends to rotate the projectile about the center of gravity G when the projectile is full of line.
C.A. Direction in which the force of the wind tends to rotate the projectile about the center of gravity I when the projectile is empty.

FIGURE 4.—Diagram showing the relative directions in which the lateral forces of the wind and the weight of the projectile act.

C. Center.
L. Direction of wind.
W. Weight.

*Plate VIII.*

This plate shows the Hunt projectile and shore-can in position for firing from the 3-inch Lyle life-saving gun A, and the method of firing.

## HUNT'S LIFE-SAVING PROJECTILE.

This apparatus consists of a projectile and a tin can known as the shore-can. It is intended for life-saving purposes to be used in connection with a gun or mortar of suitable dimensions.

### I.—DESCRIPTION.

#### 1. THE PROJECTILE—CALIBER, 3 INCHES.

*Plate I.*

The body of the shot or projectile is composed of a tin tube closed at the front end by a disk of iron. The head or point* is made of lead cast upon the end of the tin tube. The lead extends up the sides of the tube, forming a thin coating for a distance of 3″.2 from the plane of the head. The diameter of the flat head is 2.9 inches, but when fired expands to the full size of the bore. The tube is reinforced for 6 inches of its length above the lead with a galvanized sheet-iron tube. The object of this reinforce is to strengthen the tube and prevent upsetting when fired. Near the rear end of the tube four trapeziform pieces of tin termed "wings" are soldered to the tube at right angles to each other and equidistant circumferentially for the purpose of guiding the projectile in its flight after the manner of the barbs of an arrow. About 250 yards of small line is coiled on a spindle in a lathe, after passing through a saturating solution of paraffine. This coil is wrapped with a thickness of laboratory paper, and when withdrawn from the lathe-spindle is placed in the tin tube. The exterior end of the line is made fast to a wire loop which projects from the rear end of the tube. The wire is soldered to the tube. The rear end of the tube is then closed with a wooden plug one inch (1″) in thickness and of the same diameter as the inside of the cylinder. An axial hole one inch in diameter serves for the line to pass through in escaping from the shot. A paper disk is pasted over this end of the projectile, which must be removed before firing in order to secure and withdraw the end of the line.

#### 2. THE SHORE-CAN.

*Plate II.*

This can contains the shore-line and is made of tin. It is a short cylindrical tube, of greater diameter than the body of the shot. The lower end is closed by a bottom of the same material as the cylindrical body. To the bottom a ring is attached in which is tied a line, or through which a stake is driven, to prevent the can from being carried off in firing. Holes are punched through the bottom over each side of the ring-seat, through which the end of the line belonging to the outer coil is passed and tied to secure the line to the can. This shore can contains about 250 yards of small line, coiled in a lathe and saturated with paraffine in the same manner as the line in the shot. After coiling, the line is placed in the can and the tin cover put on. The cover has a central hole 1″.6 in diameter through which the line is paid out. A strip of laboratory paper is pasted around the can so as to overlap the junction of the cover and body of the can and prevent the removal of the former. A paper disk, which must be broken before firing, is pasted over the hole in the top.

* The term "point" is used throughout this description and report in its technical sense.

### 3. PRINCIPAL DIMENSIONS.

#### *a.—Projectile.*

| | | |
|---|---|---|
| *Total length* | | 22''.6 |
| Head. Length, including coating of lead | | 3''.2 |
| Diameter before firing | | 2''.9 |
| Diameter after firing, about | | 3''.0 |
| Form of point or head | | Flat. |
| Reinforce. Galvanized sheet-iron—exterior diameter | | 2''.84 |
| Length in rear of lead coating | | 6''.0 |
| Tin case. Exterior diameter | | 2''.8 |
| Length in rear of reinforce | | 13''.4 |
| Distance of center of gravity from flat point or head of shot when coil of line is inside | | 6''.0 |
| Distance of center of gravity from flat point or head of shot when empty (*i. e.*, line all out) | | 3''.2 |
| Distance of center of figure from flat point or head of shot | | 12''.4 |
| Distance between centers of gravity and figure when line is in shot | | 6''.4 |
| Distance between centers of gravity and figure when shot is empty | | 9''.2 |
| | Sq. ft. | Sq. ins. |
| Area of flat point or head of shot | 0.049 = | 7.0685 |
| Area of longitudinal section of shot, including two opposite wings | 0.5132 = | 73.9 |

#### *b.—Shore-can.*

| | |
|---|---|
| Total length | 5''.0 |
| Exterior diameter of can | 5''.46 |
| Exterior diameter of cover | 5''.50 |
| Exit-hole in cover—diameter | 1''.60 |

### 4. WEIGHT.

| | | | |
|---|---|---|---|
| Weight of shot with line | 10.50 lbs. | to | 12.75 lbs. |
| Weight of empty shot | | | 8.75 " |
| Weight of line in shot | 3.5 | " | 4.0 " |
| Weight of shore-can and line | | | 3.75 " |

### 5. LINE.

| | |
|---|---|
| Length | 500 yards. |
| Diameter | 0.116 inch. |
| Kind of line | Twisted. |
| Material | Linen. |
| Total weight of line | 7.857 lbs. |

## II.—COST.

Twenty-five 3-inch Hunt life-saving projectiles were purchased from the inventor for experimental purposes. Five of these projectiles were ordered without the "wings." The inventor's first estimate was $15 each, including a shore-line and can for each projectile, but later he agreed to furnish them at $12 each, which was the price paid for them.

## III.—METHOD OF USING.

Suppose the gun, projectiles, and shore-can to be on the firing ground and the gun in position for firing, the operations are as follows:

Insert the powder charge, tear the paper cap from the rear end of the projectile, and draw out a couple of feet of the line; place the projectile in the bore with the flat leaden head first. Then tear the paper cap from the hole in the top of the shore-can and pull out about 2 feet of line; tie the ends of the line together and place the shore-can near the gun on the windward side. The proper elevation is then given to the piece, the priming-wire inserted in the vent, a friction-primer put in, and the gun fired.

## IV.—Experiments.

### 1. FIRST SERIES.

This series of experiments was made at Sandy Hook, N. J., by Lieut. D. A. Lyle, Ordnance Department, U. S. A., and Keeper John C. Patterson, jr., of Life Saving Station No. 1, District No. 4, and before the organization of the Board on Wreck Ordnance.

It seemed impossible to get a day when there was a head wind blowing, and after waiting two days for the direction of the wind to change it was determined to proceed with the firing. The results of the experiments, made December 20, 21, 1878, are embraced in the tabular statement given below:

## EXPERIMENTS WITH LIFE-SAVING APPARATUS AT SANDY HOOK, NEW JERSEY.

*a.—Record of firings with Hunt's life-saving projectiles. Caliber, 3 inches.*

| Date, 1878. | | | Gun. | | | Powder. | | Projectile. | | | | Shot-line, linen. | | | | | | Wind. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month. | Day. | Number of fire. | Kind. | Caliber. | Elevation. | Kind. | Weight. | Kind. | "Wings" or not. | Weight. | Time of flight. | Number. | Diameter. | Action. | Range. | Deviation of projectile right or left. | Drift of line at 300 yards' stake right or left. | Direction. | Velocity—feet per second. |
| | | | | *In.* | ° | | *Oz.* | | | *Lbs.* | *Sec.* | | *Inch.* | | *Yards.* | *Feet.* | *Feet.* | | |
| Dec. | 20 | 1 | Lyle "A" .. | 3 | 25 | Life-saving service. | 3 | Hunt .. | No .. | 11.0 | 6.5 | 4½ ‡ | ...... | Good* . | 357.66 | 0 | 90 L | | 14.166 |
| | 20 | 2 | .. do .... | 3 | 25 | .. do ..... | 3 | ..do .. | Yes . | 11.5 | 8.25 | 3½ | 0.116 | Fair .. | 443.5 | 30 L | 151 L | | 11.39 |
| | 20 | 3 | ....do .... | 3 | 25 | ....do .... | 3 | ..do ... | Yes . | 12.25 | 6.5 | 3½ | 0.116 | Good | 503. | 71 L | 163 L | | 20.41 |
| | 20 | 4 | ....do .... | 3 | 25 | ....do ..... | 3 | ..do .. | Yes . | 12.25 | 8.0 | 3½ | 0.116 | Good .. | 502.33 | 150 L | 168 L | | 11.72 |
| | 20 | 5 | ....do ..... | 3 | 22 | ... do ..... | 3 | ..do ... | Yes . | 12.25 | 7.? | 3½ | 0.116 | Good .. | 475. | 252 L | 215 L | | 14.16 |
| | 20 | 6 | ...do .... | 3 | 22 | ....do ..... | 3 | ..do ... | Yes . | 12.5 | 7.5 | 3½ | 0.116 | Fair ... | 478. | 210 L | 240 L | | 13.33 |
| | 21 | 7 | ....do ..... | 3 | 25 | ... do ..... | 3 | ..do ... | Yes . | 12.5 | 7.5 | 3½ | 0.116 | Good .. | 433. | 3 R | †† | | Calm. |
| | 21 | 8 | ....do ..... | 3 | 25 | ....do ..... | 3 | ..do ... | No .. | 12.5 | 7.5 | 3½ | 0.116 | Good .. | 435. | 99 R | †† | | Almost calm. |


**Remarks.**

| | *Lbs.* |
|---|---|
| Average weight of shot and line, about ........ | 12.25 |
| Weight of shot, empty . | 8.75 |
| Weight of line in shot, about | 3.50 |
| Weight of "shore-line" (?) its tin can .......... | 3.75 |

**TESTS OF HUNT SHOT-LINE.**

Size: ‡ "No. 3½," ? diameter = 0".116.

| No. of sample. | Breaking weight. | Amt. of stretch in 6 feet of line. | Remarks. |
|---|---|---|---|
| | *Lbs.* | *In.* | |
| 1 | 132 | 4 | Line made of linen, twisted, and saturated with paraffine when coiled. |
| 2 | 125 | 4 | |
| 3 | 129 | 4 | |

* By "good" in this column is meant that the line ran out of shot without breaking or tangling in large knots. Small knots were not taken into account.
† Drift of line about the same as deviation of shot, not measured.
‡ This line is a little larger than "No. 3½" and smaller than "No. 4" Silver Lake.

*b.—Synoptical transcript of notes from the firing record. Hunt's life-saving projectile and 3-inch Lyle bronze gun A.*

| Date. | Number of round. | |
|---|---|---|
| 1878. | | |
| Dec. 20 | 1 | Shot without "wings" turned over and over about shorter axis throughout trajectory. A little of the line left in the shot. Good line shot. |
| 20 | 2 | Shot with wings. Rotated about shorter axis for 250 yards and then continued point first to end of trajectory. Shot carried off shore-line can. |
| 20 | 3 | Shot with wings. Rotated as before. Line all out of shot. |
| 20 | 4 | Shot carried out all line in itself and "shore-can." Carried can 200 yards down the range. |
| 20 | 5 | Time of flight uncertain, as falling snow made shot indistinct. Gun pointed a little to the left by mistake, which accounts for a portion of the drift in the line noted in the record. Falling snow rendered range-flags obscure. Shore-cans carried down the beach. All line out. |
| 20 | 6 | Shot with "wings." All line carried out. Can carried down the beach by the line. |
| 21 | 7 | Instead of shore-line a faking-box "B" and Silver Lake line No. 4½ were used. The line in the shot was attached directly to the braided line in the faking-box. About 200 yards of line was drawn from the faking-box. |
| 21 | 8 | No remarks. The combined lengths of line in the shot and "shore-can" proved to be too short for the ranges obtained on December 20, as four out of six of the "shore-cans" were carried down the range, distances varying from 50 yards to 200 yards, which would have been a very serious matter had the shots been fired out to sea to effect communication with a stranded vessel. |

## 2. SECOND SERIES.

The experiments comprising this series were made by and under the direction of the Board on Wreck Ordnance, under the Treasury Department.

The lack of a proper firing ground and adverse winds when the ordnance-proving ground at Sandy Hook was available caused the experiments to be postponed from time to time. There were so few projectiles at the disposal of the board that it was not deemed advisable to expend any more until a head and cross wind should be obtained. These causes, together with the diverse and pressing duties of the several members of the board in connection with their other labors, rendered it extremely difficult to obtain the presence of a majority of them upon any particular date. Several attempts were made to continue the firing, but they were each time frustrated by sudden changes of wind, which would continue to blow with a provoking pertinacity from the wrong quarter. At length, on October 21, 1880, the board succeeded in getting a head wind, and though it was only a brisk breeze, varying from 12 to 15 miles, and in one instance to 17 miles per hour, it was decided to make the most of it. Accordingly, 10 shots were fired in rapid succession before the wind changed direction. The last shot of the series of October 21st was fired over a range measured at right angles to the direction of the wind, which was blowing from the left side with a velocity of 15.34 miles per hour. (See Plate III, Fig. I.) The results are given herewith, presented in tabular form. The last round in the table (No. 11) was fired on October 25, 1880, with a wind from the right and *rear*, blowing at the rate of 17.476 miles, or nearly 17½ miles per hour.

## EXPERIMENTS WITH LIFE-SAVING APPARATUS AT SANDY HOOK, NEW JERSEY.

*a.—Record of firings with Hunt's life-saving projectiles. Caliber, 3 inches.*

| Date, 1878. Month. | Day. | Number of fire. | Gun. Kind. | Gun. Caliber. | Elevation. | Powder. Kind. | Powder. Weight. | Projectile. Kind. | Projectile. "Wings" or not. | Projectile. Weight. | Projectile. Time of flight. | Shot-line, linen. Number. | Shot-line, linen. Diameter. | Shot-line, linen. Action. | Range. | Deviation of projectile right or left. | Drift of line at 300 yards' stake right or left. | Wind. Direction. | Wind. Velocity—feet per second. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *In.* | ° | | *Oz.* | | | *Lbs.* | *Sec.* | | *Inch.* | | *Yards.* | *Feet.* | *Feet.* | | |
| Dec. | 20 | 1 | Lyle "A" .. | 3 | 25 | Life-saving service. | 3 | Hunt .. | No .. | 11.0 | 6.5 | 4½‡ | ...... | Good*. | 357.66 | 0 | 90 L | W | 14.166 |
| | 20 | 2 | .. do .... | 3 | 25 | do .... | 3 | ..do .. | Yes. | 11.5 | 8.25 | 3½ | 0.116 | Fair .. | 443.5 | 30 L | 151 L | | 11.39 |
| | 20 | 3 | ....do .... | 3 | 25 | ....do .... | 3 | ..do ... | Yes. | 12.25 | 6.5 | 3½ | 0.116 | Good | 503. | 71 L | 163 L | | 20.41 |
| | 20 | 4 | ....do .... | 3 | 25 | ....do .... | 3 | ..do .. | Yes. | 12.25 | 8.0 | 3½ | 0.116 | Good. | 502.33 | 150 L | 168 L | | 11.72 |
| | 20 | 5 | ....do ..... | 3 | 22 | .. do .... | 3 | ..do ... | Yes. | 12.25 | 7.7 | 3½ | 0.116 | Good. | 475. | 252 L | 215 L | | 14.16 |
| | 20 | 6 | ...do .... | 3 | 22 | ...do .... | 3 | ..do ... | Yes. | 12.5 | 7.5 | 3½ | 0.116 | Fair .. | 478. | 210 L | 240 L | | 13.33 |
| | 21 | 7 | ....do ..... | 3 | 25 | .. do .... | 3 | ..do ... | Yes. | 12.5 | 7.5 | 3½ | 0.116 | Good .. | 433. | 3 R | †† | | Calm. |
| | 21 | 8 | ....do ..... | 3 | 25 | ....do ..... | 3 | ..do ... | No .. | 12.5 | 7.5 | 3½ | 0.116 | Good .. | 435. | 99 R | †† | | Almost calm. |

PLANE OF FIRE

**Remarks.**

| | *Lbs.* |
|---|---|
| Average weight of shot and line, about ............ | 12.25 |
| Weight of shot, empty .. | 8.75 |
| Weight of line in shot, about | 3.50 |
| Weight of "shore-line" (?) its tin can .......... | 3.75 |

**TESTS OF HUNT SHOT-LINE.**

Size: ‡ "No. 3½," ? diameter=0".116.

| No. of sample. | Breaking weight. | Amt. of stretch in 6 feet of line. | Remarks. |
|---|---|---|---|
| | *Lbs.* | *In.* | |
| 1 | 132 | 4 | Line made of linen, twisted, and saturated with paraffine when coiled. |
| 2 | 125 | 4 | |
| 3 | 129 | 4 | |

* By "good" in this column is meant that the line ran out of shot without breaking or tangling in large knots. Small

† Drift of line about the same as deviation of shot, not measured.

‡ This line is a little larger than "No. 3½" and smaller than "No. 4" Silver Lake.

*firing record. Hunt's life-saving projectiles 3 inches.*

regularly throughout trajectory. The wire loop ine came off when the line was all out of the to the ground. After freeing itself from the the sand and bushes and was lost. The range ween the firing point and the free end of the

ajectory.
about one of its shorter axes. All the line ot cut the line, whose loose end was found wooden plug in the rear end of the shot line. Shot lost.
times; angle of fall great.
t its shorter axis; line parted from shot;

shot; wire loop pulled out; shot lost.
rotated about shorter axis throughout

t in trajectory helicoidal and very ir-

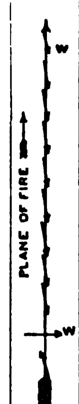
ne of fire; shot rotated three times of both shot and shore-can; shot and -can carried 27 yards to the front in loose coils near the empty shot. as 265 feet to the right, or greater (*See Plate III, Fig.* 1.)
-can carried 147 feet to the front

ind-line 3.75 pounds. iot, 792 feet. Total bably intended that shore-can (made of right and on a line hen it was placed very coil drawn ed through hot ardens slightly nning out. In greater at the experiments nd that the , difficult to was expe- her being d left for ater had ich and ly per-

riments be- lowing table

## EXPERIMENTS WITH LIFE-SAVING APPARATUS AT SANDY HOOK, NEW JERSEY.

*a.—Record of firings with Hunt's life-saving projectiles. Caliber, 3 inches.*

| Date, 1880. | | | Gun. | | | Powder. | | Projectile. | | | | Shot-line, linen. | | | | | | Wind. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month. | Day. | Number of fire. | Kind. | Caliber. | Elevation. | Kind. | Weight. | Kind. | "Wings" or not. | Weight. | Time of flight. | Number. | Diameter. | Action.* | Range. | Deviation of projectile right or left. | Drift of line at 300 yards' stake right or left. | Direction. | Velocity—feet per second. | Remarks. |
| | | | | In. | ° | | Ozs. | | | Lbs. | Secs. | | Inch. | | Yards. | Feet. | Feet. | | | |
| Oct. | 21 | 1 | Lyle "A" .. | 3 | 25 | Life-saving service. | 3 | Hunt.. | Yes. | 12.5 | Not taken. | This line is larger than "No. 3½" and smaller than "No. 4" Silver Lake lines. | 0.116 | Good.. | 382 | 13.5 L | 10. L |  | 25.0 | Army service primers, short, used in these trials. |
| | 21 | 2 | ....do ..... | 3 | 25 | ....do ...... | 3 | ..do ... | Yes. | 12.25 | | | 0.116 | Good.. | 398 | 7.0 R | 25.5 R | | 23.5 | |
| | 21 | 3 | ....do ..... | 3 | 25 | ....do ...... | 3 | ..do ... | Yes. | 12.25 | | | 0.116 | Good.. | 409 | 1.5 L | 8.0 R | | 18.3 | |
| | 21 | 4 | ....do ..... | 3 | 25 | ....do ...... | 3 | ..do ... | Yes | 11.25 | | | 0.116 | Cut off. | 360 | 45.0 R | 55.0 R | | 20.1 | |
| | 21 | 5 | ....do ..... | 3 | 25 | ....do ...... | 3 | ..do ... | Yes. | 12.5 | | | 0.116 | Good.. | 403 | 6.0 R | 12.0 R | | 20.5 | |
| | 21 | 6 | ....do ..... | 3 | 25 | ....do ...... | 3 | ..do ... | Yes | 12.5 | 7.5 | | 0.116 | Good.. | 387.33 | 34.0 L | 34.0 L | | 22.5 | |
| | 21 | 7 | ....do ..... | 3 | 22 | ....do ...... | 3 | ..do ... | Yes | 12.0 | 6.25 | | 0.116 | Good.. | 389 | 5.5 R | 2.0 R | | 22.0 | |
| | 21 | 8 | ....do ..... | 3 | 22 | ....do ...... | 3 | ..do ... | No.. | 11.25 | 5.75 | | 0.116 | Good.. | 336.66 | 44.0 L | 27.0 L | | 23.7 | |
| | 21 | 9 | ....do ..... | 3 | 22 | ....do ...... | 3 | ..do ... | No.. | 10.75 | 6. | | 0.116 | Good.. | 304.66 | 25.0 L | 25.0 L | | 22.5 | |
| | 21 | 10 | ....do ..... | 3 | 25 | ....do ...... | 3 | ..do ... | Yes | 10.5 | 7. | | 0.116 | Good.. | 410 | 103.0 R | 251.0 R | | 22.5 | |
| | 25 | 11 | ....do ..... | 3 | 25 | ....do ...... | 3 | ..do ... | No.. | 10.5 | 7.75 | | 0.116 | Good.. | 474.66 | 2.0 L | 51.0 L | | 27.5 | |

* The term "good" in this column means that no large knots or snarls formed in the line. Small knots, caused by the catching of a few coils upon each other, but which were drawn through the hole in the wooden plug or that in the shore-can, were marked as "good."

*b.—Synoptical transcript of notes from the firing record. Hunt's life-saving projectiles Caliber 3 inches.*

| Date. | Number of round. | |
|---|---|---|
| 1880. | | |
| October 21 | 1 | Shot rotated about shorter axis irregularly throughout trajectory. The wire loop which attached the shot to the line came off when the line was all out of the can, and the end of the line fell to the ground. After freeing itself from the line the shot passed out of sight in the sand and bushes and was lost. The range was measured by the distance between the firing point and the free end of the line. |
| 21 | 2 | Action of the shot and line good. |
| 21 | 3 | Projectile wabbled throughout the trajectory. |
| 21 | 4 | Projectile rotated three or four times about one of its shorter axes. All the line drawn out of shot. Wire loop on shot cut the line, whose loose end was found 360 yards from the firing point. The wooden plug in the rear end of the shot was pulled out and remained on the line. Shot lost. |
| 21 | 5 | Shot rotated about shorter axis several times; angle of fall great. |
| 21 | 6 | Shot rotated horizontally four times about its shorter axis; line parted from shot; wire loop pulled out; shot lost. |
| 21 | 7 | Shot rotated five times; line parted from shot; wire loop pulled out; shot lost. |
| 21 | 8 | No "wings" on projectile. The latter rotated about shorter axis throughout trajectory; motion very irregular. |
| 21 | 9 | No "wings" on projectile; motion of shot in trajectory helicoidal and very irregular. |
| 21 | 10 | Direction of wind perpendicular to the plane of fire; shot rotated three times about shorter axis; all the line carried out of both shot and shore-can; shot and line drifted badly "with the wind"; shore-can carried 27 yards to the front from the firing point. The line was found in loose coils near the empty shot. The drift of the line at the 200-yards stake was 265 feet to the right, or greater than the drift opposite the 300-yards stake. (*See Plate III, Fig.* 1.) |
| 25 | 11 | No "wings" on projectile; all line out; shore-can carried 147 feet to the front from the firing point. |

## *c.—Remarks.*

*October* 21, 1880.—Weight of shore-can and hand-line 3.75 pounds. Length of line in can, 720 feet; length of line in shot, 792 feet. Total length of line in shot and can, 1,512 feet. It was probably intended that the shot and can should contain 750 feet each. The shore-can (made of tin), containing the hand-line, was placed 4 feet to the right and on a line with the muzzle of the gun, except in round No. 10, when it was placed 4 feet on the left of the gun, on the windward side. Every coil drawn out of the shot put a twist in the line. The line is passed through hot paraffine when coiled by the maker, which in cooling hardens slightly and binds the coils together and prevents tangling in running out. In the majority of cases on this date the drift of the line was greater at the 200 yards stake than at the 300 yards stake. In former experiments with this projectile, made in warmer weather, it was found that the paraffine with which the line is saturated made it slippery, difficult to grasp, and that in attempts to haul upon it great difficulty was experienced to prevent its slipping through the hands. The weather being cold a length of the line was placed in the cold salt water and left for several minutes; when removed it was found that the cold sea-water had hardened the paraffine and had made the line harsh to the touch and much less slippery. Hauling upon the line could be more readily performed without very much slipping.

## *d.—Velocities of the wind.*

Station, Sandy Hook, N. J.; date October 21, 1880. Experiments began at about 1.20 p. m., and ended at 2.30 p. m. The following table

gives the velocities of the wind as indicated by the self-registering anemometer on the United States Signal Service building during the experiment:

Height of anemometer above ground, 40 feet 7 inches.

| Time P. M. | Velocity of the wind. Miles per hour. |
|---|---|
| 1.20 | 24 |
| 1.30 | 20 |
| 1.40 | 20 |
| 1.50 | 20 |
| 2.00 | 20 |
| 2.10 | 20 |
| 2.20 | 20 |
| 2.30 | 16 |

The surface velocities of the wind at the firing point, as indicated by a delicate Casella anemometer, are given below for each shot fired between 1.20 p. m. and 2.30 p. m. on October 21, 1880:

Height of instrument above ground, 6 feet.

| No. of round. | Velocity of wind in— | |
|---|---|---|
| | Feet per second. | Miles per hour, approximately. |
| 1 | 25.0 | 17.0 |
| 2 | 23.5 | 16.0 |
| 3 | 18.3 | 12.5 |
| 4 | 20.1 | 14.0 |
| 5 | 20.5 | 14.0 |
| 6 | 22.5 | 15.4 |
| 7 | 22.0 | 15.0 |
| 8 | 23.7 | 16.0 |
| 9 | 22.5 | 15.4 |
| 10 | 22.5 | 15.4 |

It will be noticed that the velocities given by the self-registering anemometer are greater than those given by the Casella instrument. This is partly due to the difference in altitude, but more to the fact that the heavier instrument develops sufficient momentum during the intervals, when the wind is brisk, to keep up the rotation during the intervals marked by temporary lulls in the force of the wind. The small mass of the Casella rotating wheel favors its ready response to the slightest variations in the strength of the wind. Its indications are more accurate than those of the coarser and heavier instruments, and have been accepted as standard measurements.

### 3. THIRD SERIES.

This series of experiments was made in order to institute a direct comparison between the line-carrying properties of the Lyle and Hunt systems of projectiles. The 3-inch Lyle gun "A" was used to fire the Hunt projectile, and the service 2.5-inch Lyle gun for the Lyle projectile. The elevations given the guns in each set of shots were identical. The pieces were fired simultaneously by electricity in order to have the conditions of the atmosphere, the direction and force of the wind the same in both cases. One gun was trained to fire over the original measured range, and the other over a measured range parallel to the original one

and 35 feet distant from that range. The horizontal projections of the parallel planes of fire, the relative positions of the guns, and the arrangement of the electric wires are shown in Fig. 2, Plate III. The charge of powder, three (3) ounces, used with the Hunt projectile was the charge prescribed by Mr. Hunt in a letter written by him, dated November 7, 1878.* This charge was fifteen one-thousandths ($\frac{15}{1000}$) the weight of his projectile weighing 12.5 pounds. The six (6) ounces used the first day with the Lyle projectile is twenty one-thousandths ($\frac{20}{1000}$) of the weight of that projectile. Thus, assuming the lines to be of the same size and weight (which they were not—the Silver Lake No. 4 line being greater in diameter and weight for the same length than the Hunt line), the charge for the Lyle projectile was proportionally heavier than that for the Hunt. On the second day the board directed seven (7) ounces to be used with the Lyle projectile to see whether it would break the line or not, as the amount of powder charge was considered to be immaterial,† so long as no part of the apparatus was affected injuriously or its future usefulness impaired.

The results of the simultaneous firings are presented in the table given below.

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*Mr. Hunt, in his letter of November 1, 1878, recommends "2¼ ounces for short range and 3 ounces for long range," and states in his letter of November 7, 1878, "3 ounces of powder will be all that is needed to throw out the line."

†From its small cost and from the small limits within which charges for life-saving purposes may vary.

# EXPERIMENTS WITH LIFE-SAVING APPARATUS AT SANDY HOOK, NEW JERSEY.

*a.—Record of simultaneous firings with the Lyle and Hunt systems.*

| Date, 1880. | | Gun. | | | | Powder. | | Projectile. | | | | | | | | Shot-line. | | | | | | | Wind. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month. | Day. | Kind. | Caliber. | No. of fire. | Elevation. | Kind. | Weight. | Kind. | Marks. | Weight. | Time of flight. | Range. | Deviation, right or left. | Drift, at 300 yards, right or left. | Primer. | Material. | How made. | Number. | Length. | Diameter. | Weight. | Action. | Direction. | Velocity—feet per second. | Remarks. |
| | | | In. | | ° | | Oz. | | | Lbs. | Secs. | Yds. | Feet. | Feet. | | | | | Yds | Ins. | Lbs. | | | | |
| Oct. | 23 | Lyle | 2.5 | 1 | 25 | Life-saving service. | 6 | Lyle, service | L. 4 | 18.43 | Lost | 443 | 57 L | 195 L | Electric cannon. | Linen, W. P. | Braided | 4 | 700 | 0.148 | 14 | Good | | 15 | 1st set, fired together. |
| | 23 | do | 3 | 2 | 25 | do | 3 | Hunt | | 12.25 | 7.25 | 450 | 33 L | 202 L | do | Linen, (Hunt) | Twisted | 3½† | 500 | 0.116 | 7* | Good | | 15 | |
| | 23 | do | 2.5 | 3 | 25 | do | 6 | Lyle, service | L. 12 | 18.75 | Lost | 435 | 35 L | 179 L | do | Linen, W. P. | Braided | 4 | 700 | 0.148 | 14 | Good | | 15 | 2d set, fired together. |
| | 23 | do | 3 | 4 | 25 | do | 3 | Hunt | | 12.25 | 7.25 | 425 | 77 L | 204 L | do | Linen, (Hunt) | Twisted | 3½† | 500 | 0.116 | 7* | Good | | 15 | |
| | 25 | do | 2.5 | 5 | 22 | do | 7 | Lyle, service | L. 12 | 18.75 | 7 | 470 | 0 | 43 L | do | Linen, W. P. | Braided | 4 | 700 | 0.148 | 14 | Good | | 25.7 | 3d set, fired within 10 seconds; primer missed fire in 1 gun. |
| | 25 | do | 3 | 6 | 22 | do | 3 | Hunt | | 12.75 | 5.75 | 416⅔ | 10 R | 35 L | do | Linen, (Hunt) | Twisted | 3½† | 500 | 0.116 | 7.857* | Good | | 25.7 | |
| | 25 | do | 2.5 | 7 | 22 | do | 7 | Lyle, service | L. 12 | 18.75 | 6.75 | 464 | 55 L | 117 L | do | Linen, W. P. | Braided | 4 | 700 | 0.148 | 14 | Good | | 20.4 | 4th set, fired together. |
| | 25 | do | 3 | 8 | 22 | do | 3 | Hunt | | 12.5 | 6.25 | 444⅓ | 38 L | 147 L | do | Linen, (Hunt) | Twisted | 3½† | 500 | 0.116 | 7.25* | Good | | 20.4 | |


* Weights of line in both shot and shore-can.
† The Hunt lines have been classed at "No. 3½," but they are larger than the Silver Lake "No. 3½," and are neither so large nor so heavy as the "No. 4" line used with the Lyle projectile.

*b.—Synoptical transcript of notes from the firing record. Simultaneous firings of Lyle and Hunt systems of life-saving projectiles.*

| Date. | No. of set. | No. of round. | Remarks. |
|---|---|---|---|
| 1880. | | | |
| October 23 | 1st | 1 | LYLE PROJECTILE.—Time of flight lost by observer. Began firing at 9.27 a. m. |
| 23 | | 2 | HUNT PROJECTILE.—Shot suddenly changed direction and crossed No. 1's line below the 300-yard point. The projectile ran "up in the eye of the wind," due to a sudden gust of wind. These two shots were fired at the same instant by means of electricity, in order to make a direct comparison, both projectiles being influenced by the same force of wind. |
| 23 | 2d | 3 | LYLE PROJECTILE.—Time of flight lost; action of line good. Drift of line less at 200-yards stake than at 300 yards. |
| 23 | | 4 | HUNT PROJECTILE.—Drift of line 25 yards greater at 200-yards stake than at 300 yards. All the line carried out. Wire loop in shot not pulled out. The two shots forming this set were fired at the same instant by electricity, at 9.46 a. m. |
| 25 | 3d | 5 | LYLE PROJECTILE.—Used iron faking-box B. Unbleached linen line No. 4. |
| 25 | | 6 | HUNT PROJECTILE.—Shore-can carried out 51 feet toward the front. These shots were fired within 10 seconds of each other; the primer failed to explode one charge. |
| 25 | 4th | 7 | LYLE PROJECTILE.—Used iron faking-box B. Loose coils found near shot. |
| 25 | | 8 | HUNT PROJECTILE.—Action of line good. Loose coils found near shot. These two shots were fired simultaneously. |

The supply of Hunt projectiles having been exhausted, the trials were brought to a close.

## V.—USE OF LARGER LINES.

As has been seen in the foregoing pages, the size of the Hunt lines falls between the Nos. 3½ and 4 Silver Lake lines. It is also evident that the tin case of the Hunt projectile, even if its diameter be increased to 3″.5, will not contain a greater length of line of a larger diameter than it now does of the smaller line. The latter line, as has been shown, is already short enough when the maximum charge of 3 ounces of powder is used. The Lyle projectile has energy enough to carry lines Nos. 4½, 5, 6, 7, 8, and 9 made by Silver Lake Company, and weighing 13, 24, 33, 33 to 38, 50.5, and 55.5 pounds, respectively, in addition to carrying the No. 4 service line, which is itself larger than the Hunt line. The lines in use in service at present are Nos. 4, 7, and 9, the two latter being beyond both the containing and carrying capacity of the light Hunt projectile.

It is evident from the size of the case of the Hunt projectile that it could not contain a sufficient length of even a No. 7 line to be of much practical value, and the project of putting a No. 9 line, such as has been issued to the service, in this shell is simply impracticable.

Mr. Hunt has stated that he would prefer a gun and projectile of 4″ or 4″.5 caliber instead of the smaller caliber submitted. It should be borne in mind that this would increase the surface and volume of the projectile without increasing its weight in the same proportion.

There is an instance on record where an 8-inch projectile, constructed on the same principle as the Hunt projectile, but intended to carry a heavier (No. 7) line, has been tried and proved a failure.

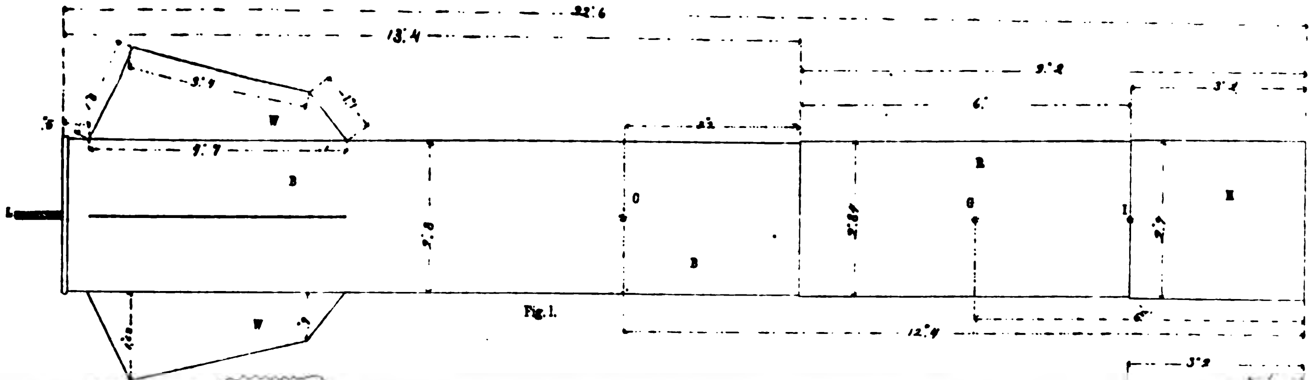


Fig. 1.

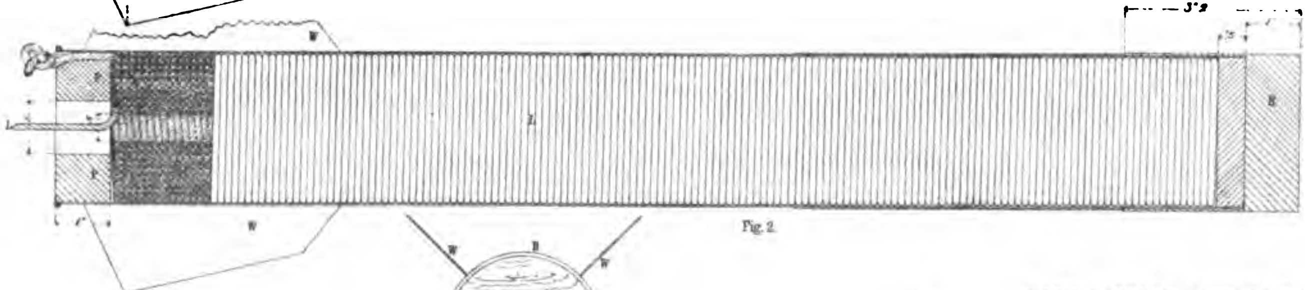


Fig. 2.

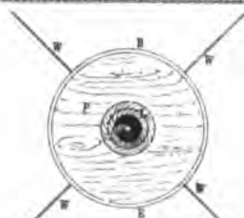


Fig. 3.

LIFE-SAVING APPARATUS.

HUNT'S

3-INCH LIFE-SAVING PROJECTILE,

FOR

LIFE-SAVING PURPOSES.

1881.

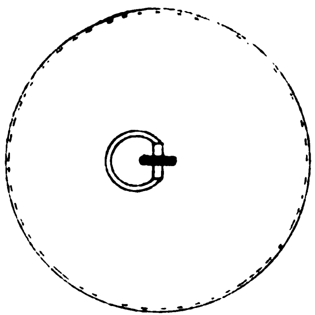


Fig. 3.

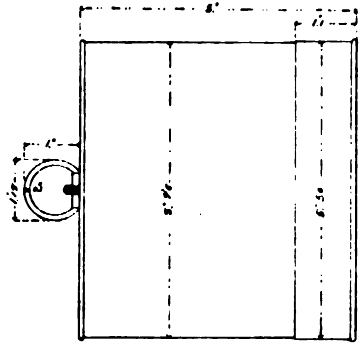


Fig. 1.

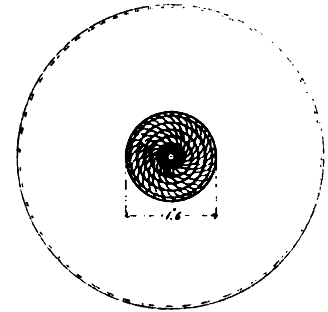


Fig. 2.

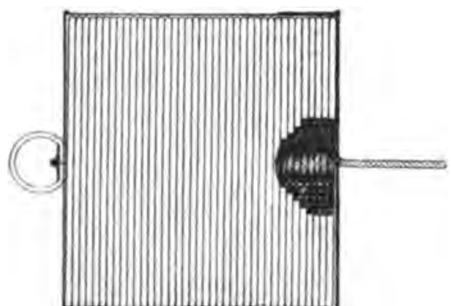


Fig. 4.

LIFE-SAVING APPARATUS.

# HUNT'S SHORE CAN,

FOR USE WITH THE

8-inch Hunt Life-Saving Projectile,

FOR

LIFE-SAVING PURPOSES.

1881.

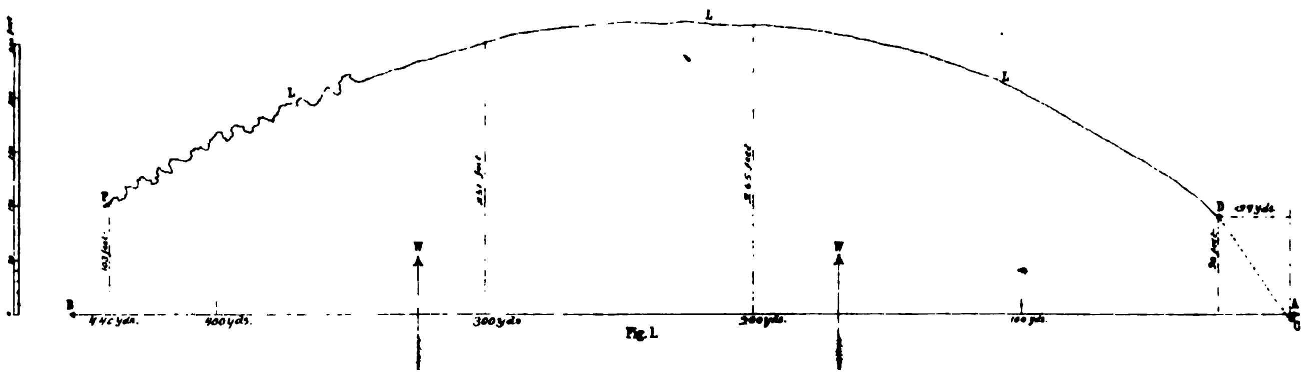



Fig. 1.

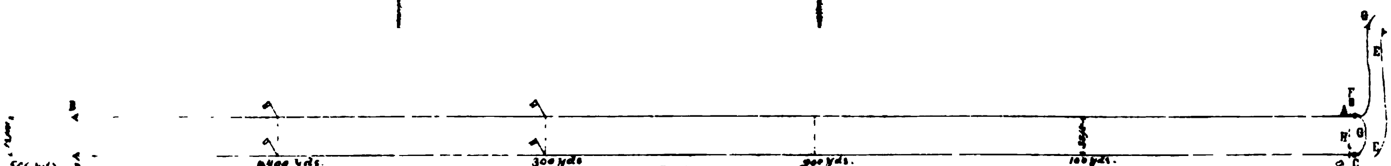



Fig. 2.

LIFE-SAVING APPARATUS.

DIAGRAMS

SHOWING

The Effect of a Transverse Wind

UPON THE

HUNT PROJECTILE AND LINE,

AND THE

*Arrangement for Firing in the Comparative Trials of*

OCTOBER 23-25, 1880

1881.

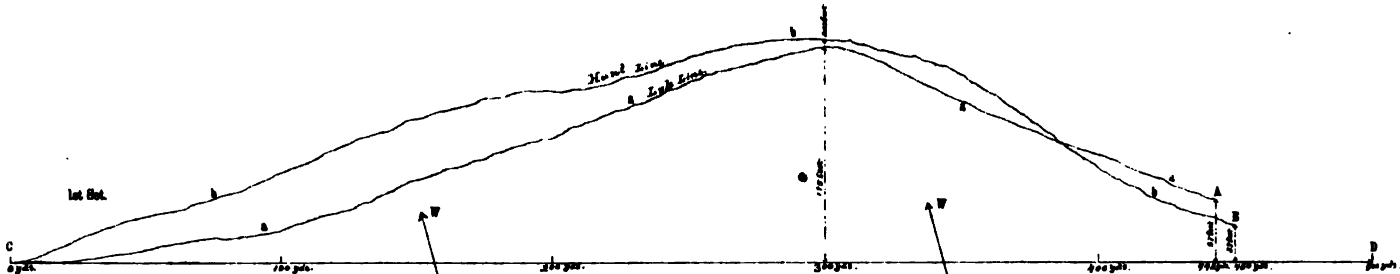



Fig. 1.

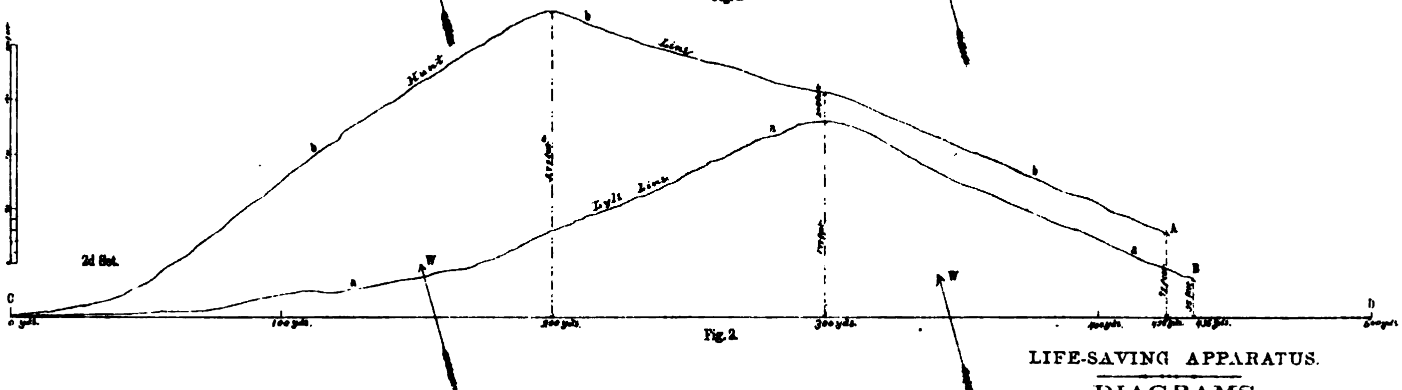



Fig. 2.


LIFE-SAVING APPARATUS.

DIAGRAMS

SHOWING THE

Relative Positions on the Ground

OF THE

LYLE AND HUNT SHOT LINES,

In the Simultaneous Firings of

OCTOBER 23, 1880.

1881.

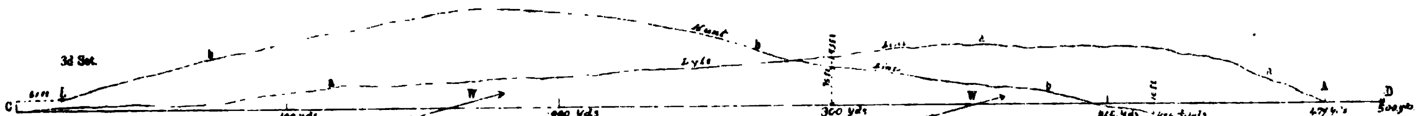



Fig. 1.

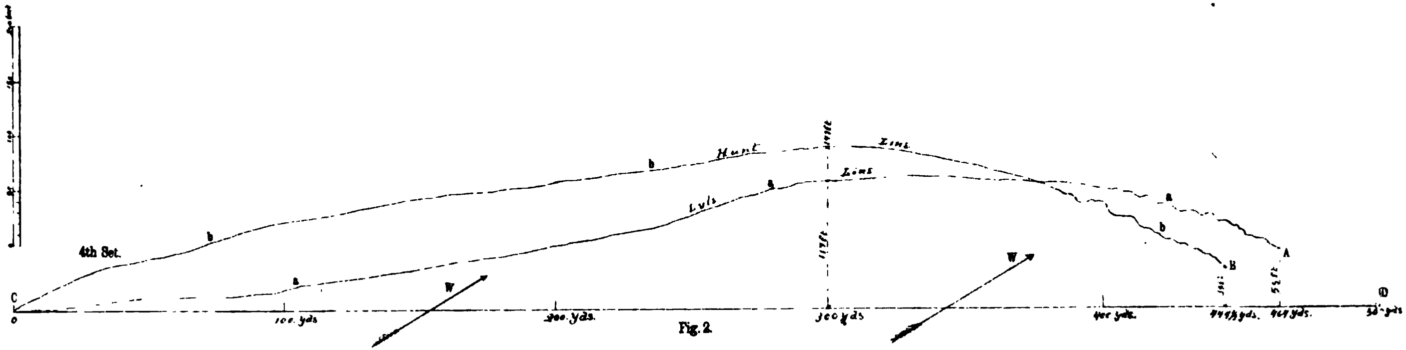
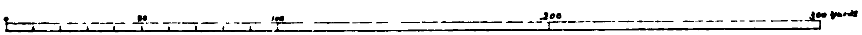



Fig. 2.




LIFE-SAVING APPARATUS.

DIAGRAMS

SHOWING THE

**Relative Positions on the Ground**

OF THE

LYLE AND HUNT SHOT LINES.

In the Simultaneous Firings of

**OCTOBER 25, 1880.**

1881.

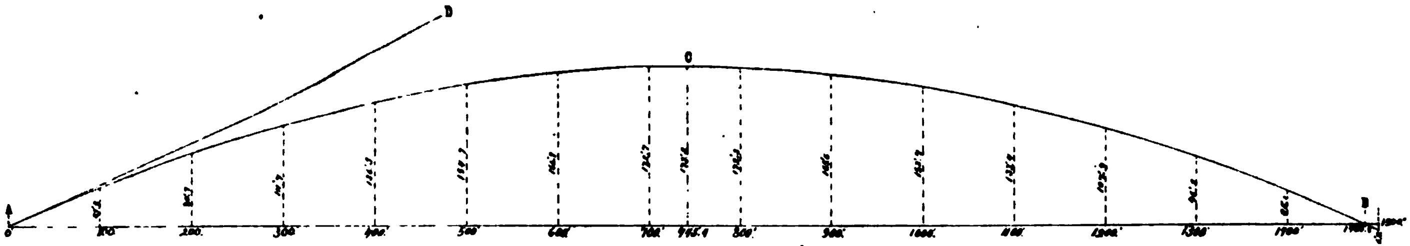



Fig. 1.

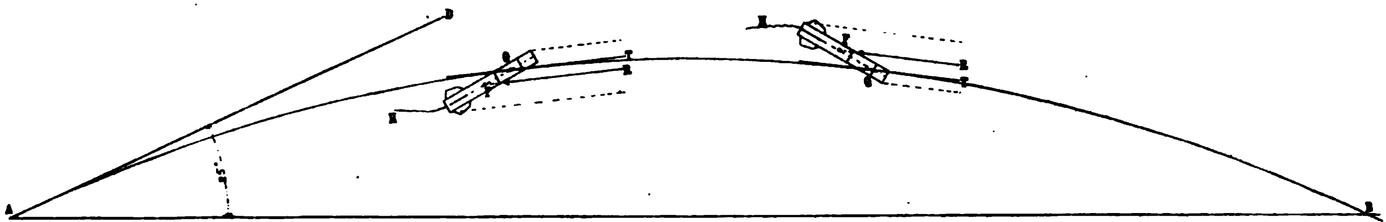



Fig. 2.

LIFE-SAVING APPARATUS.

DIAGRAMS SHOWING THE NORMAL TRAJECTORY

FOR AN

Angle of Projection of 25 degrees, and an Initial Velocity of 250 feet per second.

ALSO

Showing the action of the Resistance of the Air upon the Hunt projectile.

1881.

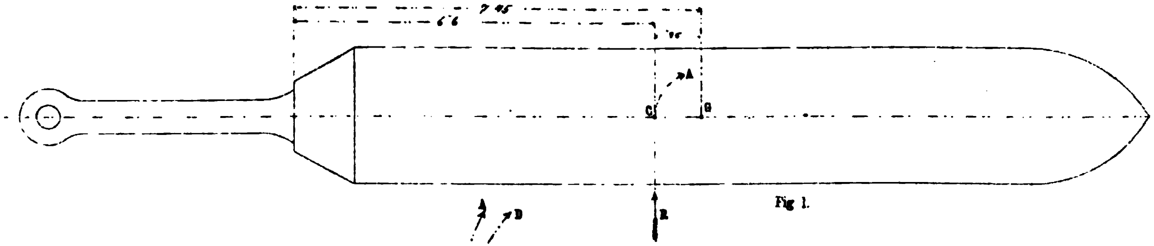



Fig 1.

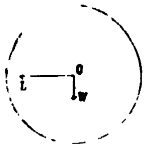



Fig. 2.

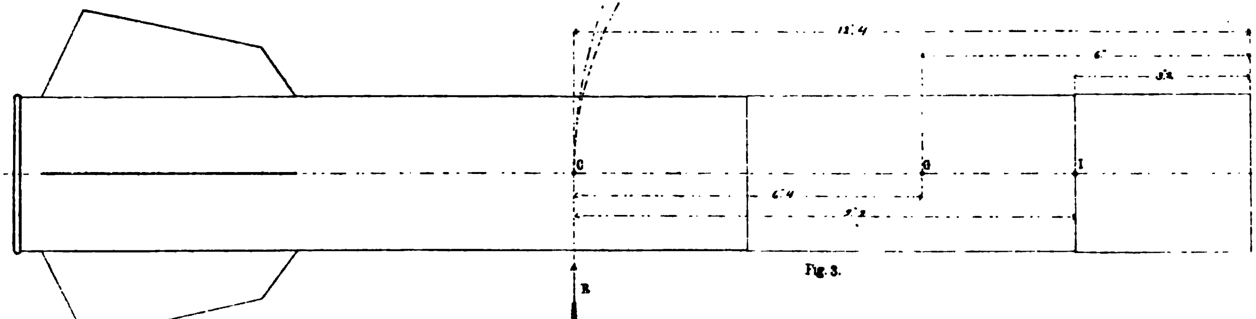



Fig. 3.

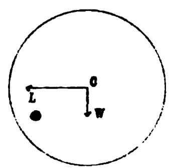



Fig. 4.

LIFE-SAVING APPARATUS.

DIAGRAMS

OF THE

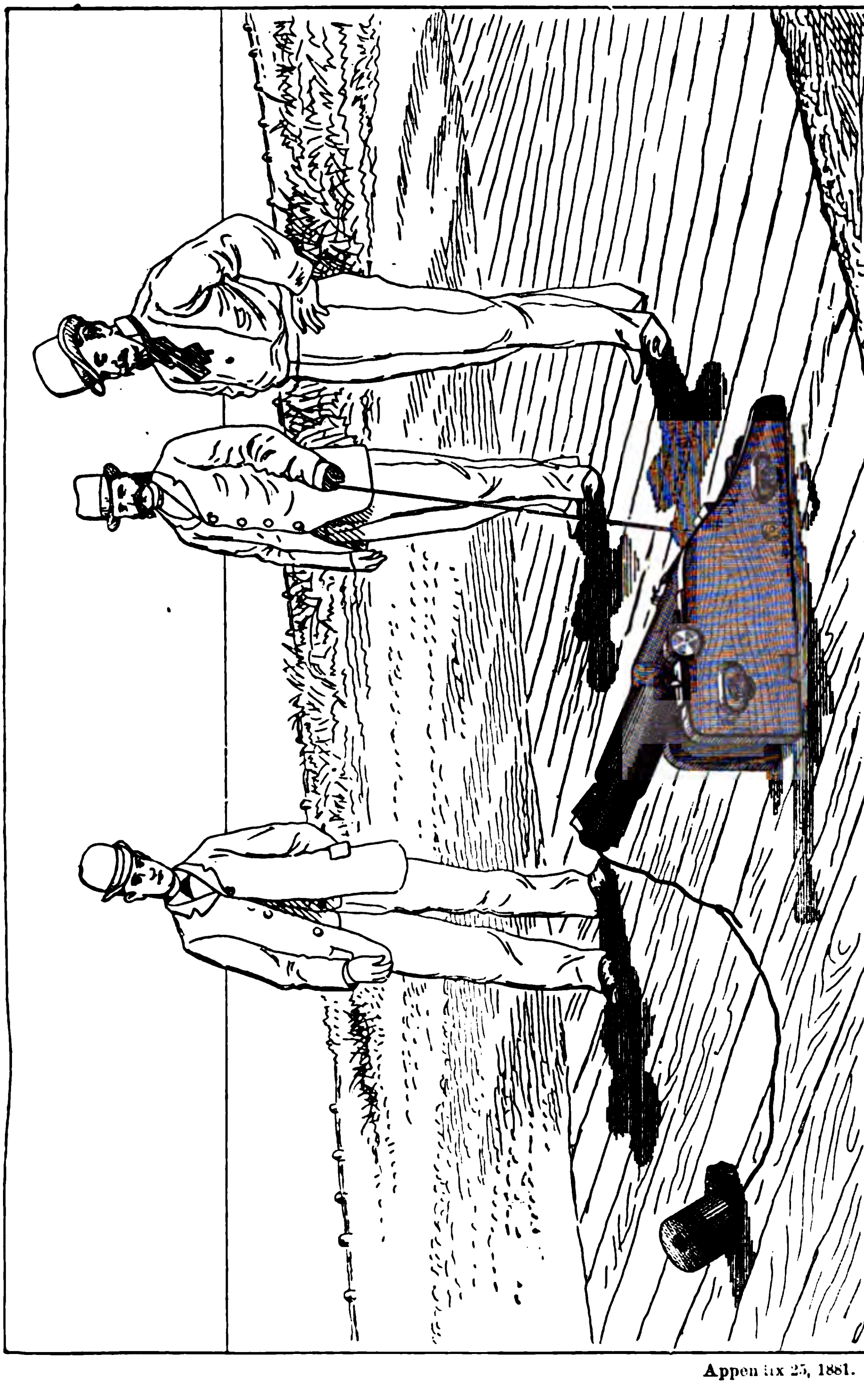
LYLE AND HUNT L. S. PROJECTILES,

SHOWING THE

Action of lateral winds to produce a motion of rotation about the centers of gravity.

1881.

PLATE VIII.



Appendix 25, 1881.

# APPENDIX 26.

## REPORT ON SPONGE, SPONGE COVER, AND CARTRIDGE-BAG FOR THE LIFE-SAVING APPARATUS.

BY LIEUT. D. A. LYLE, ORDNANCE DEPARTMENT.

(One plate.)

The articles described below complete the equipment of the Lyle life-saving gun. The figures in the accompanying plate are working drawings, giving all necessary dimensions.

### SPONGE.

*Plate* I, *Fig.* 2.

The sponge-staff and rammer have been described* in Lieutenant Lyle's report for 1878, and a drawing of the implement is shown in Plate III, Fig. 6, of that report, but no reference was made to the dimensions of the material. The sponge is composed of two pieces, either of sheep-skin with the wool on, or of the usual sponge-cloth heretofore described. One piece is circular to form the head, the other rectangular to form the body of the sponge. The head is sewed to the body and then the sponge placed on the staff, the edges of the body drawn together, and the whole fastened to the staff by means of long copper tacks.

*Dimensions.*

| | Inches. |
|---|---|
| Head: circular. | |
| Diameter | 1.9 |
| Body: rectangular. | |
| Length | 5.0 |
| Width | 6.0 |

These pieces are cut out by means of patterns of wood or sheet-metal

### SPONGE COVER.

*Plate* I, *Figs.* 3, 4, *and* 5.

This cover is made of white duck or canvas, and is designed to protect the sponge from sand and rain. Like the sponge, it is composed of two pieces, one circular the other rectangular. The head is sewed to the end of the body and the longitudinal edges sewed together, after which the cover is turned inside out, bringing the projecting edges on the inside. The mouth or open end of the canvas cylinder has a hem run around it, through which is passed a twine cord to draw it together and bind it to the staff. A knot is tied in each end of the twine to prevent its being drawn through the hem. A loop of bridle leather is sewed to the circular end to facilitate the removal of the cover from the sponge.

* *Vide* Report on Life-saving Ordnance, 1878, by Lieut. D. A. Lyle, Ordnance Department, U. S. A., page 76; also Report of Chief of Ordnance, U. S. A., 1878, page 250; and Report of Operations of U. S. Life-saving Service, 1878, page 292.

*Dimensions.*

| | Inches. |
|---|---|
| Head: circular. | |
| Diameter | 3.2 |
| Body: rectangular. | |
| Length | 10.25 |
| Width | 9.25 |
| Strap (for loop). | |
| Length | 6.0 |
| Width | 0.75 |

SERVICE CARTRIDGE-BAG (large).

*Plate* I, *Fig.* 6.

This is made of serge or other woolen material. The diagram shows one of the half-bags. The dotted line 0″.5 from the edge indicates the position of the seam.

*Dimensions*

| | Inches. |
|---|---|
| Total length | 8.7 |
| Total width | 4.5 |
| Width between seams | 3.5 |
| Distance from seam to edge | 0.5 |
| Radius of semicircular end | 2.25 |

EXPLANATION OF PLATE.

Fig. 1. Developed cylindrical body of sponge.
Fig. 2. Circular end of sponge.
Fig. 3. Developed cylindrical body of sponge cover.
Fig. 4. Circular end of sponge cover.
Fig. 5. Development of loop on end of cover.
Fig. 6. Half cartridge-bag (large, service).

NATIONAL ARMORY, June 2, 1881.

LIFE-SAVING APPARATUS.

## DETAILS OF SPONGE, SPONGE COVER, AND Service Cartridge Bag, (large.)

1879.

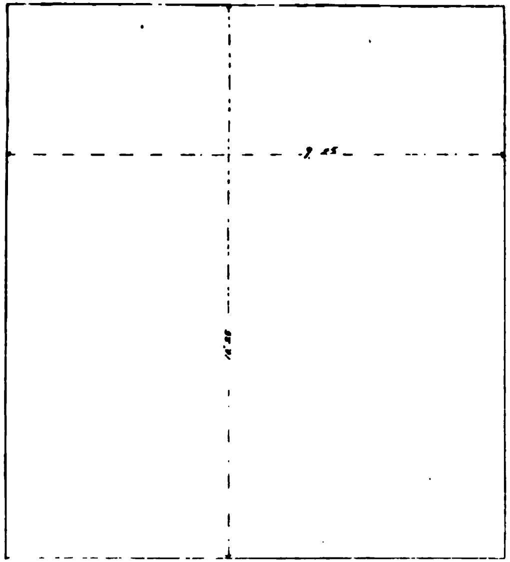


Fig. 3.

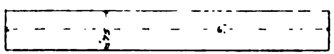


Fig. 5.

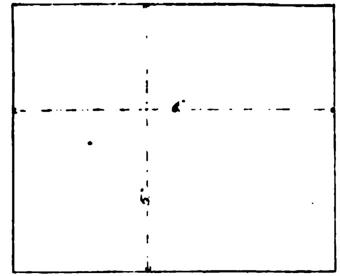


Fig. 1.

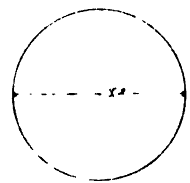


Fig. 4.

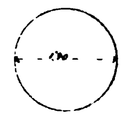


Fig. 2.

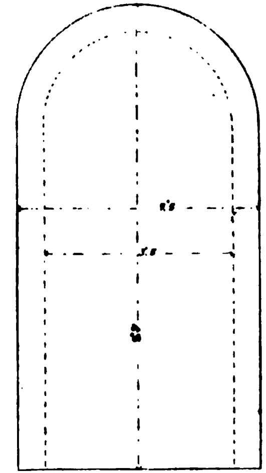
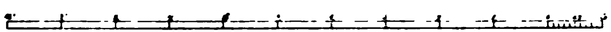


Fig. 6.



# APPENDIX 27.

REPORT ON THE MANUFACTURE OF ONE THOUSAND SPURS AND STRAPS OF THE PATTERN DESIGNED BY MAJOR ANSON MILLS, TENTH CAVALRY. BY LIEUT. L. L. BRUFF, UNDER THE DIRECTION OF BVT. LIEUT. COL. D. W. FLAGLER, COMMANDING THE ROCK ISLAND ARSENAL.

(Five plates.)

SIR: In accordance with instructions, I have the honor to make the following report with regard to the Mills spurs manufactured at this arsenal:

### DESCRIPTION OF THE SPUR.

The finished spur is shown in Figs. 21 and 22. As will be seen by a reference to the plate, there are two different models of the spur, marked "Model A, small size," and "Model B, small size," the difference being in the shape and assembling of the leather parts, the metal parts being the same in both.

The spur shown in Fig. 21, model A, small size, is composed of a heel-strap, *a*, or "main leather band," as it is called by the inventor, to which the rowel-plate *b* is riveted, a lower strap, or under strap *c*, passing under the boot; and a spur-strap, *d*.

These parts are shown in Figs. 14, 13, and 12. The metallic parts of the spur are the rowel-plate *b* (Fig. 21), the yoke or frame *e*, the shoulder *h* (all of brass in one piece), the rowel *f* of steel, the rowel-pin of steel, the buckle *k* of brass, eyelet *l*, and the brass rivets and burs, marked 1, 2, and 3. Fig. 22 shows the second model, marked model B, small size; *a* is the heel-strap and *b* the spur-strap. In this model the under-strap and spur-strap are continuous, passing through slits in the ends of the heel-strap, as represented in the figure. The different leather parts belonging to this model are shown in detail in Figs. 18 and 19.

In the model A, small size, Fig. 21, the buckle is fastened to the under-strap by means of a small projection *c* (Fig 13), which is twined over the bar of the buckle and riveted, the tongue passing through the slot. In Fig. 22, model B, small size, the buckle is fastened to the spur-strap with a rivet, as shown in Fig. 19.

The buckle is shown in Figs. 19 and 20. The eyelet *l* (Fig. 21) is intended for the insertion of a button attached to a steel wire double loop for strapping down the trowsers. None of these loops have been made here.

Two sizes of the leather parts for the spur model A can be made, the larger size being shown in Figs. 15, 16, and 17, but they were found to be so large and clumsy when completed that only the small size was made at the request of the inventor.

The size of the leather parts for the model B can be varied by lengthening the heel-strap and spur-strap. Five hundred pairs of each model, small size, were made.

## MANUFACTURE OF THE METAL PARTS.

With the models submitted by the inventor were drawings of a press for making the brass part of the spur. The models of spurs submitted were made in two pieces, one being the rowel-plate and the other the yoke or frame supporting the rowel, which was riveted to the rowel-plate. Drawings were also furnished, showing the spur with rowel-plate and yoke in a single piece, and the inventor wished the spur made by the latter method. The press above mentioned was intended to make the spur in a single piece, but owing to the cost of making the press and the small number of spurs ordered (1,000 pairs), it was determined to change the plan of manufacture, as indicated in the drawings submitted, and to use the machinery already in the shop, so as to avoid the extra cost.

The different steps in the process of manufacture of the rowel-plate and yoke are shown in Figs. 1, 2*a*, 3, 4*a*, 5, 6, and 7.

The plate and yo e are first punched out flat, as shown in Fig. 1, in a rotary press, from No. 16 sheet brass. The middle slot and the holes for the rivets and rowel-pin (Fig. 2*a*) are then punched. The branches of the yoke are next rounded and bent up (Fig. 3) by means of a punch and die of proper shape. The branches are then bent as in Fig. 4*a*, Fig. 4*b* showing another view of the spur at the end of this operation. The shoulder is then formed (Fig. 5), and by the next operation set firmly down on the rowel-plate (Fig. 6). The holes *a a* (Fig. 7) are then drilled, and the finished rowel-plate and yoke are as represented (Fig. 7).

The rowel plate and yoke are then pickled and polished. It has been found that there is some difficulty in polishing the spurs after they are in this shape, and it is recommended that in future the polishing be done while the spur is as represented in Fig. 2*a*.

The rowel is punched out in blank from No. 15 sheet steel, as shown in Fig. 8.

The hole for the rivet is then drilled or punched, and the rowels are then strung on a wire passing through the hole, placed in the milling machine, and the teeth milled out, as in Fig. 10. Fig. 11 shows the rivet. It is made of steel wire No. 10.

## THE BUCKLES.

The buckles are shown in Figs. 19 and 20. They were cast here, as they could not be purchased of the proper shape and size.

The tongue is made of brass wire No. 13. The dimensions are shown in the drawings.

## THE LEATHER PARTS.

These are shown in Figs. 12, 13, 14, 15, 16, 17, 18, and 19. Figs. 12, 13, 14, 15, 16, and 17 show the small and large sizes of leather parts for the spur model A (Fig. 21), and Figs. 18 and 19 the parts for the spur model B (Fig 22). The large size leathers for the latter model are not given, as none of the spurs of that size were made and no model furnished. In Fig. 13 it will be noticed that the under-strap marked *c* has a projection *c′* for the buckle at one end, and a cut or slot *c″* at the other.

As the projection is intended to fasten the buckle, it will be on the right side in the right spur and on the left side in the left spur.

The slot *c″* is cut out to diminish the thickness of the leather at the

eyelet (where the leathers are riveted together). The holes to be punched in the different straps, for the rivets, eyelets, rowel-plates, and buckles, are shown in the drawings.

The end of the under-strap at $c''$ is shaved down to diminish the thickness of leather.

### ASSEMBLING THE PARTS.

The rowel is riveted in the yoke with a rotary press. The rivet is increased in diameter throughout its entire length by this operation, and the hole in the rowel is made $\frac{1}{16}''$ larger than the rivet to allow for this increase.

The rowel-plate is riveted to the heel-strap by the same press, as it was found impossible to do the riveting by hand without the plate. The leather parts are assembled after the rowel-plate has been riveted. In the spur model A, the spur-strap and heel-strap are placed together and the eyelet inserted; the heel-strap and under-strap on the other side are then assembled in the same manner; the end of the under-strap with the slot in it is then inserted between the heel-strap and spur-strap, and the whole riveted. The holes punched in the straps serve as guides for making the others.

### METALLIC PARTS FOR 1,000 PAIRS MILLS' SPURS.

| | Pounds. |
|---|---|
| No. 16 sheet brass, soft (rowel-plate and yoke) | 232 |
| No. 15 sheet steel (rowels) | 58 |
| No. 10 steel wire (rivets for rowels) | 6¼ |
| No. 13 brass wire (buckle tongues) | 5 |
| Cast brass (for buckles) | 63 |

### PARTS FOR LEATHER WORK.

| | | |
|---|---|---|
| For 500 pairs spurs, model A, small size: | | |
| Collar leather, 6 to 7 ounces per square foot | 490 | square feet. |
| Brass rivets, ⅜″, No. 12 | 23 | pounds. |
| Brass burs, No. 12 | 5 5/16 | pounds. |
| Eyelets, ¼″ by ¼″, tinned | 2,000 | |
| Bar buckles, ⅞″, brass (like drawing) | 1,000 | |
| For 500 pairs spurs, model B, small size: | | |
| Collar leather, 6 to 7 ounces per square foot | 290 | square feet. |
| Brass rivets, ⅜″, No. 12 | 12 | pounds. |
| Brass burs, No. 12 | 1 | pound. |
| Brass bar buckles, ⅞″ (like drawing) | 1,000 | |

Fig.1.

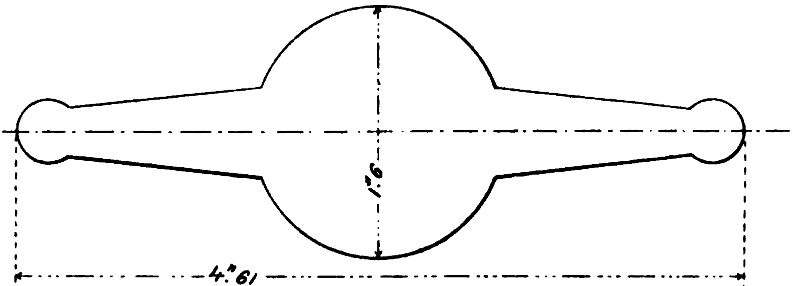



Fig. 2 a.

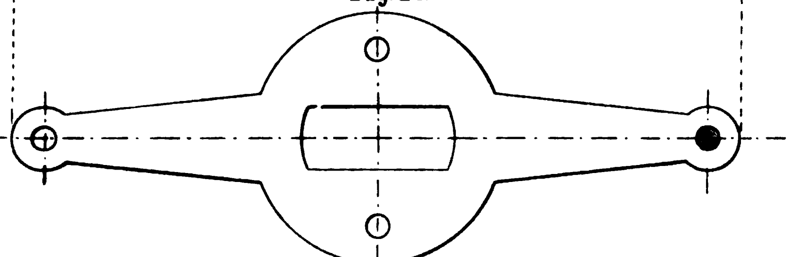


Fig. 2 b.

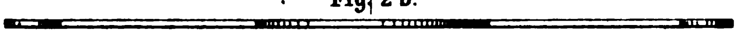


Fig. 3.

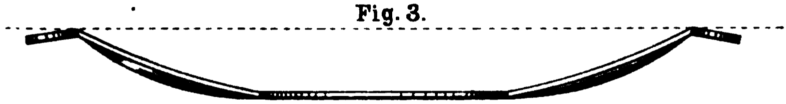


Fig. 4 a.

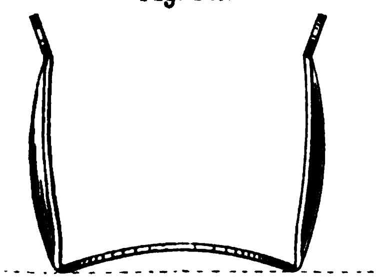


Fig. 4 b.

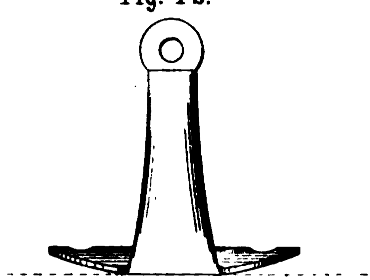


Fig. 5.

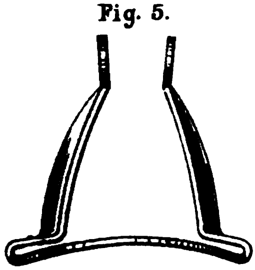
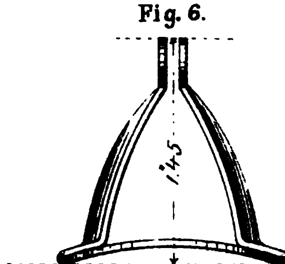
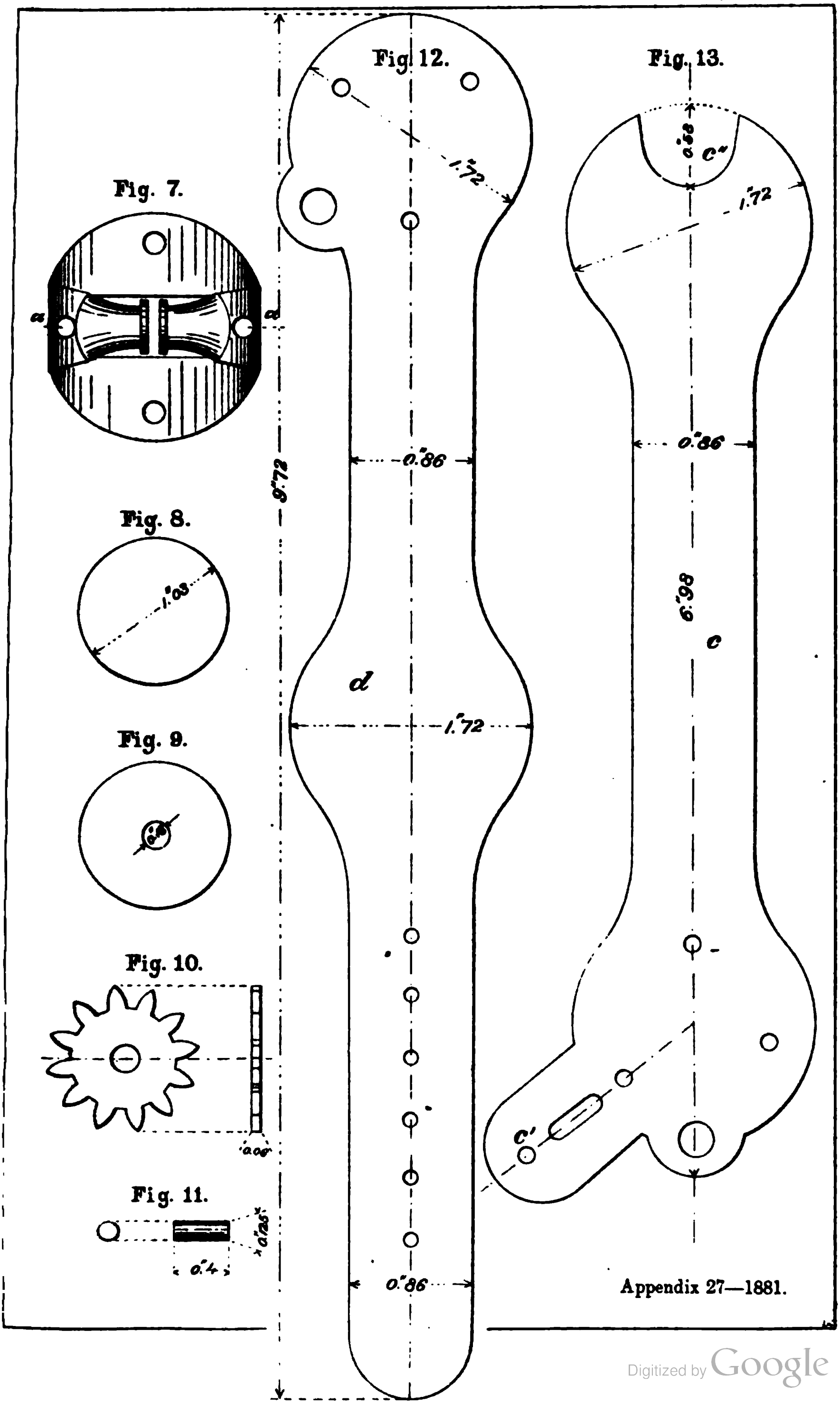


Fig. 6.






Appendix 27—1881.

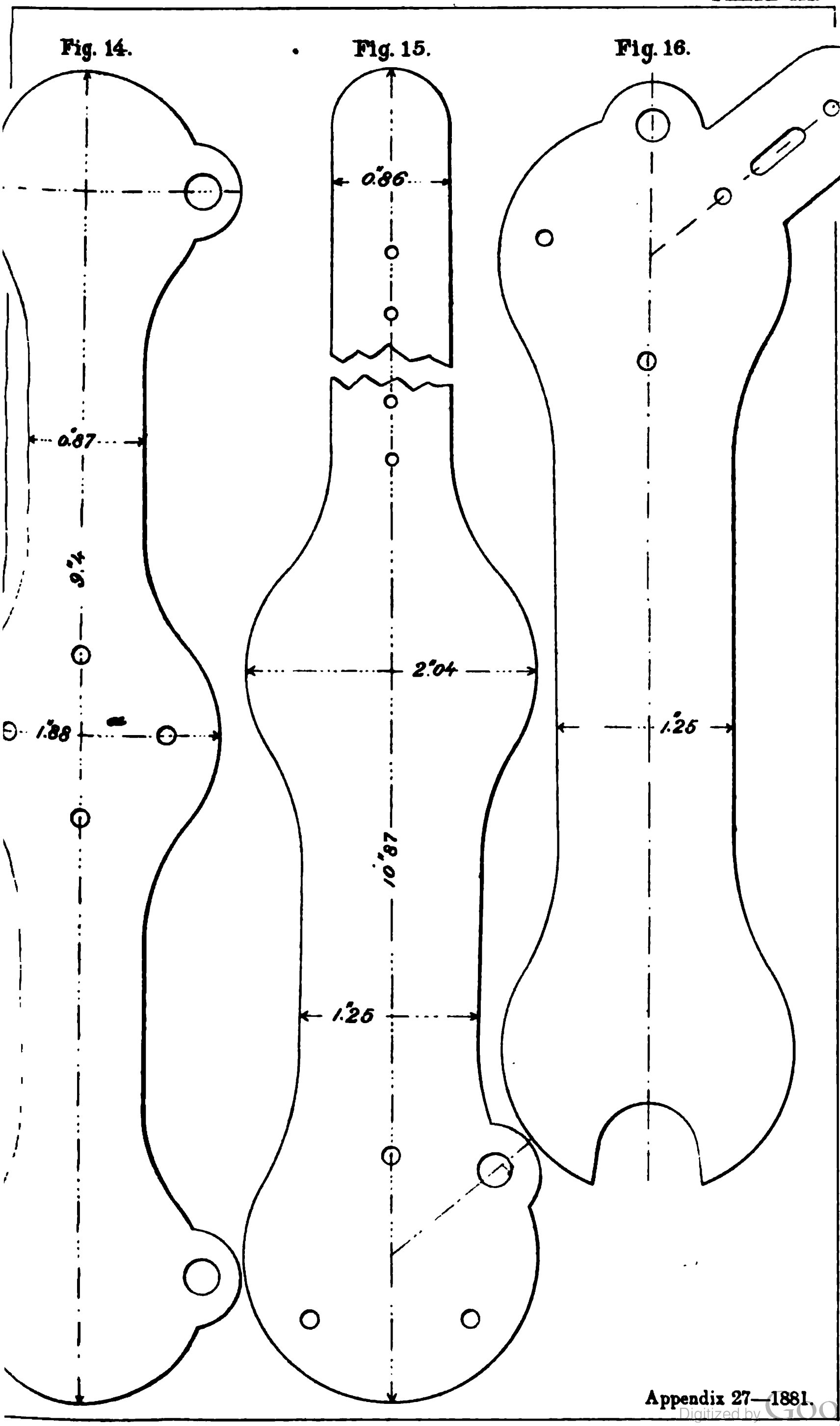


Fig. 14.
Fig. 15.
Fig. 16.
0.87
9.4
1.88
0.86
2.04
10.87
1.25
1.25

Fig. 21.

MODEL "A" – SMALL SIZE.

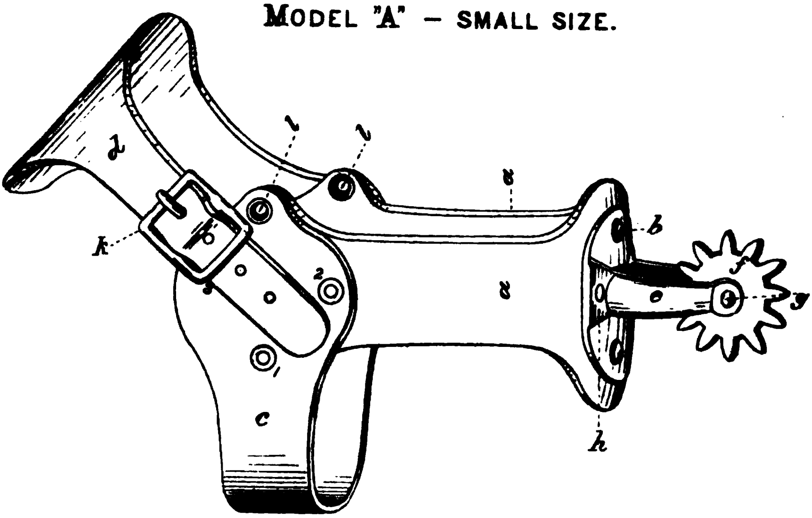
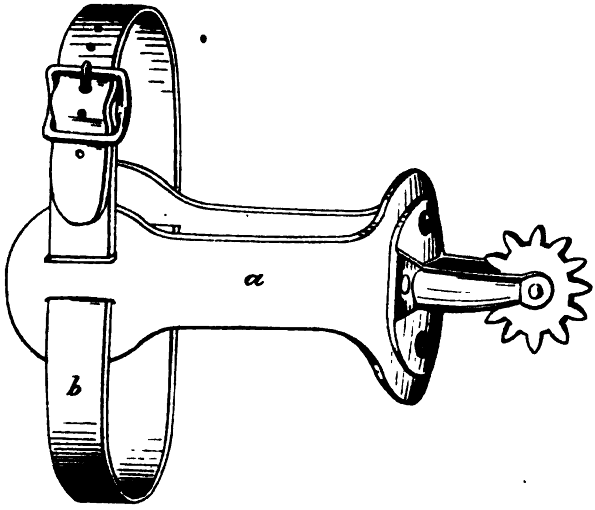



Fig. 22.

MODEL "B" – SMALL SIZE.



# APPENDIX 28.

## REPORTS ON EXPERIMENTAL CARTRIDGES CONTAINING 70 AND 80 GRAINS OF POWDER AND 500 GRAINS OF LEAD, MANUFACTURED AT FRANKFORD ARSENAL.

(One plate.)

NATIONAL ARMORY, SPRINGFIELD, MASS.,
*March* 11, 1881.

SIR: In accordance with your instructions to test the experimental cartridges—70 and 80 grains powder, 500-grain round pointed bullets—recently received from Frankford Arsenal, I have the honor to submit the following sheets, showing accuracy at 500 and 800 yards. The 80-grain cartridges were fired in the six-groove rifle (the long-range Springfield), and 70 grains in the service rifle.

Both kinds of cartridges have been fired with peep and globe, also ordinary service sights.

Sheets are also submitted showing the accuracy obtained with the 70-grain cartridge, as made by hand at this armory, fired from four ordinary service rifles, two having a left-hand twist, while endeavoring to determine a drift curve for the experimental bullet.

It will be seen from the former sheets that the 70-grain cartridge in the service rifle gives equally good results with the 80-grain charge in the long-range rifle provided with a costly sight, while neither bears any comparison to those obtained with unselected service guns with the 70-grain cartridge prepared at this post.

This simply goes to confirm the statement made in my report of October 25, 1880, that "improvement in accuracy is to be sought for in the cartridge and not in the gun." It is unknown what powder was used in the Frankford cartridges, but the Springfield were loaded with Dupont received from Frankford Arsenal.

Very respectfully, your obedient servant,

JOHN E. GREER,
*Captain of Ordnance.*

To the COMMANDING OFFICER NATIONAL ARMORY.

500 *yards range.—March* 5, 1881.

| Rifle. | Sight. | Powder. | | Bullet. | | | No. of targets. | Deviations. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Weight. | Kind. | Weight. | Caliber. | Kind. | | M. H. | M. V. | M. A. |
| | | *Grs* | | *Grs.* | | | | | | |
| Springfield, long-range, 6 grooves, 19½" twist. | Open service.... | 80 | Unknown. | 500 | .455 | Frankford, $\frac{1}{16}$ tin. | 1 | 4.9 | 4.1 | 6.4 |
| Do........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 2 | 3.4 | 6.8 | 7.6 |
| Do........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 3 | 5.1 | 4.2 | 6.6 |
| Do........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 4 | 4.0 | 4.4 | 5.9 |
| | | | | | | | Mean. | 4.3 | 4.8 | 6.6 |

500 *yards range.—March* 5, 1881—Continued.

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs* | | *Grs.* | | | | | | |
| Springfield, long-range, 6 grooves, 19[illegible]″ twist. | Peep and globe, Sharp's. | 80 | Unknown. | 500 | .455 | Frankford, $\frac{1}{16}$ tin. | 1 | 5.7 | 6.6 | 8.7 |
| Do ........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 2 | 3.2 | 5.6 | 6.5 |
| Do ........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 3 | 2.3 | 4.6 | 5.2 |
| Do ........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 4 | 6.4 | 4.6 | 7.9 |
| | | | | | | | Mean. | 4.4 | 5.3 | 7.1 |

500 *yards range.—March* 9, 1881.

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| Springfield, long-range, 6 grooves, 19[illegible]″ twist. | Peep and globe, Bull's. | 80 | Unknown. | 500 | .455 | Frankford, $\frac{1}{16}$ tin. | 1 | 6.7 | 8.7 | 11.0 |
| Do ........ | Peep and globe, Sharp's. | 80 | ....do ..... | 500 | .455 | ....do ..... | 2 | 4.2 | 4.2 | 6.0 |
| Do ........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 3 | 4.4 | 7.2 | 8.4 |
| | | | | | | | Mean. | 5.1 | 6.7 | 8.4 |
| Do ........ | Open service .... | 80 | ....do ..... | 500 | .455 | ....do ..... | 1 | 6.0 | 4.6 | 7.6 |
| Do ........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 2 | 6.9 | 5.8 | 9.0 |
| | | | | | | | Mean. | 6.4 | 5.2 | 8.3 |
| Springfield, service. | ....do ........... | 70 | ....do ..... | 500 | .455 | ....do ..... | 1 | 7.0 | 4.0 | 8.1 |
| Do ........ | Peep and globe, Sharp's. | 70 | ....do ..... | 500 | .455 | ....do ..... | 1 | 4.3 | 7.1 | 8.3 |

800 *yards range.—March* 7, 1881.

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| Springfield, long-range, 6 grooves, 19[illegible]″ twist. | Peep and globe, Sharps'. | 80 | Unknown. | 500 | .455 | Frankford, $\frac{1}{16}$ tin. | 1 | 6.4 | 7.8 | 10.1 |
| Do ........ | Open service .... | 80 | ....do ..... | 500 | .455 | ....do ..... | 1 | 8.7 | 9.0 | 12.5 |
| Springfield, service. | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 1 | 8.9 | 9.1 | 12.7 |
| Do ........ | Peep and globe, Sharps'. | 80 | ....do ..... | 500 | .455 | ....do ..... | 1 | 6.8 | 6.6 | 9.5 |

800 *yards range.—March* 8, 1881.

| Rifle. | Sight. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| Springfield, long-range, 6 grooves, 19[illegible]″ twist. | Peep and globe, Bull's. | 80 | Unknown. | 500 | .455 | Frankford. | 1 | 11.4 | 19.6 | 22.7 |
| Do ........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 2 | 8.5 | 7.7 | 11.5 |
| Do ........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 3 | 3.8 | 17.6 | 18.0 |
| Do ........ | Peep and globe, Sharps'. | 80 | ....do ..... | 500 | .455 | ....do ..... | 4 | 11.5 | 18.7 | 22.0 |
| Do ........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 5 | 6.0 | 20.3 | 21.2 |
| | | | | | | | Mean. | 8.2 | 16.8 | 19.3 |
| Do ........ | Open service .... | 80 | ....do ..... | 500 | .455 | ....do ..... | 1 | 9.5 | 8.4 | 12.7 |
| Do ........ | ....do ........... | 80 | ....do ..... | 500 | .455 | ....do ..... | 2 | 6.4 | 11.7 | 13.3 |
| | | | | | | | Mean. | 7.9 | 10.0 | 13.0 |
| Springfield, service. | ....do ........... | 70 | ....do ..... | 500 | .455 | ....do ..... | 1 | 8.0 | 13.1 | 15.3 |
| Do ........ | Peep and globe, Sharps'. | 70 | ....do ..... | 500 | .455 | ....do ..... | 1 | 6.4 | 11.9 | 13.5 |

### 200 *yards range.—February* 26, 1881.

| Rifle. | Twist. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | Deviations. M. H. | Deviations. M. V. | Deviations. M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Grs.* | | *Grs.* | | | | | | |
| Service | Right. | 70 | Dupont | 500 | .4555 | Springfield | 1 | 2.8 | 2.4 | 3.7 |
| Do | Left | 70 | do | 500 | .4555 | do | 2 | 1.0 | 1.4 | 1.7 |
| Hotchkiss | Right. | 70 | do | 500 | .4555 | do | 3 | 1.4 | 2.5 | 2.9 |
| Do | Left | 70 | do | 500 | .4555 | do | 4 | 2.5 | 1.6 | 3.0 |
| Service | Right | 70 | do | 500 | .4555 | do | 5 | 2.1 | 2.5 | 3.3 |
| Do | Left | 70 | do | 500 | .4555 | do | 6 | 1.3 | 1.8 | 2.2 |
| Hotchkiss | Right. | 70 | do | 500 | .4555 | do | 7 | 1.2 | 2.3 | 2.6 |
| Do | Left | 70 | do | 500 | .4555 | do | 8 | 1.9 | 2.1 | 2.8 |
| | | | | | | | Mean | 1.8 | 2.07 | 2.8 |

### 400 *yards range.—February* 26, 1881.

| Rifle. | Twist. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | M. H. | M. V. | M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| Service | Right | 70 | Dupont | 500 | .4555 | Springfield | 1 | 7.0 | 2.3 | 7.4 |
| Do | Left | 70 | do | 500 | .4555 | do | 2 | 5.5 | 2.9 | 6.2 |
| Hotchkiss | Right | 70 | do | 500 | .4555 | do | 3 | 5.7 | 4.7 | 7.4 |
| Do | Left | 70 | do | 500 | .4555 | do | 4 | 3.4 | 3.7 | 5.0 |
| Service | Right. | 70 | do | 500 | .4555 | do | 5 | 4.9 | 6.7 | 8.8 |
| Do | Left | 70 | do | 500 | .4555 | do | 6 | 3.1 | 2.6 | 4.0 |
| Hotchkiss | Right. | 70 | do | 500 | .4555 | do | 7 | 5.1 | 5.2 | 7.3 |
| Do | Left | 70 | do | 500 | .4555 | do | 8 | 3.0 | 3.3 | 4.5 |
| | | | | | | | Mean | 4.7 | 3.9 | 6.26 |

### 600 *yards range.—February* 26, 1881.

| Rifle. | Twist. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | M. H. | M. V. | M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| Service | Right. | 70 | Dupont | 500 | .4555 | Springfield | 1 | 5.8 | 4.9 | 7.6 |
| Do | Left | 70 | do | 500 | .4555 | do | 2 | 5.5 | 5.0 | 7.4 |
| Hotchkiss | Right. | 70 | do | 500 | .4555 | do | 3 | 5.4 | 7.3 | 9.1 |
| Do | Left | 70 | do | 500 | .4555 | do | 4 | 6.3 | 4.4 | 7.0 |
| Service | Right. | 70 | do | 500 | .4555 | do | 5 | 5.3 | 5.1 | 7.4 |
| Do | Left | 70 | do | 500 | .4555 | do | 6 | 5.4 | 8.8 | 10.3 |
| Hotchkiss | Right. | 70 | do | 500 | .4555 | do | 7 | 8.3 | 2.4 | 8.6 |
| Do | Left | 70 | do | 500 | .4555 | do | 8 | 6.1 | 5.5 | 8.2 |
| | | | | | | | Mean | 6.01 | 5.4 | 8.2 |

### 800 *yards range.—February* 16, 1881.

| Rifle. | Twist. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | M. H. | M. V. | M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| Service | Right. | 70 | Dupont | 500 | .4555 | Springfield | 1 | 5.6 | 3.6 | 6.7* |
| Do | Left | 70 | do | 500 | .4555 | do | 2 | 10.0 | 7.5 | 12.5 |
| Hotchkiss | Right. | 70 | do | 500 | .4555 | do | 3 | 7.2 | 9.1 | 11.6 |
| Do | Left | 70 | do | 500 | .4555 | do | 4 | 9.5 | 5.9 | 11.2 |
| Service | Right. | 70 | do | 500 | .4555 | do | 5 | 7.9 | 10.7 | 13.3 |
| Do | Left | 70 | do | 500 | .4555 | do | 6 | 8.4 | 9.6 | 12.7 |
| Hotchkiss | Right. | 70 | do | 500 | .4555 | do | 7 | 8.4 | 7.8 | 11.5 |
| Do | Left | 70 | do | 500 | .4555 | do | 8 | 7.8 | 9.8 | 12.5 |
| | | | | | | | Mean | 8.1 | 8.0 | 11.5 |

* Best 800 yards target on record at this armory.

### 1,000 *yards range.—February* 16, 1881.

| Rifle. | Twist. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Kind. | No. of targets. | M. H. | M. V. | M. A. |
|---|---|---|---|---|---|---|---|---|---|---|
| Service | Right. | 70 | Dupont | 500 | .4555 | Springfield | 1 | 15.1 | 19.0 | 24.2 |
| Hotchkiss | Right. | 70 | do | 500 | .4555 | do | 2 | 11.2 | 17.2 | 20.5 |
| Do | Left | 70 | do | 500 | .4555 | do | 3 | 8.5 | 11.3 | 14.1 |
| Service | Right. | 70 | do | 500 | .4555 | do | 4 | 14.0 | 19.2 | 23.8 |
| Do | Left | 70 | do | 500 | .4555 | do | 5 | 11.6 | 18.6 | 21.9 |
| Hotchkiss | Left | 70 | do | 500 | .4555 | do | 6 | 12.0 | 22.3 | 25.3 |
| | | | | | | | Mean | 12.06 | 17.9 | 21.6 |

NATIONAL ARMORY, SPRINGFIELD, MASS.,
*March* 12, 1881.

Respectfully forwarded to the Chief of Ordnance, U. S. A.

I inclose herewith Captain Greer's report of a trial at this armory with the new 80-grain powder and 500-grain bullet cartridge made at the Frankford Arsenal for use in the 150 long-range Springfield rifles now being made at this armory for issue to the marksmen of the Army.

The Sharps' peep-sight used in the trial was one of the 25 lately purchased from the Sharps' Company, and described on pages 174 and 175 of "*Laidley's Rifle Practice.*"

The "Bull-sight" is one that is being prepared in connection with the trial now being made to get up a marksman rifle agreeably to the instructions contained in Ordnance Office indorsement of February 11, 1881.

The superiority of fire shown for the cartridges made by hand at this place comes, it is thought, from the bullet being slightly larger and more cylindrical in front of the crimp, giving it a more central and closer fit in the bore at the start, and it is probably for this reason that this bullet was preferred at Creedmoor last fall.

I have reason to think that this close fitting of the bullet may make it sometimes difficult to push the cartridge home when the bore is fouled, especially in cold weather.

Although not so accurate in fire as desired by army marksmen, I am of opinion that as the Frankford-made cartridge avoids this difficulty it should be preferred for issue with the long-range rifles now being made here. It is serviceable in every respect.

J. G. BENTON,
*Colonel of Ordnance, Commanding.*

FRANKFORD ARSENAL, PA., *April* 29, 1881.

Respectfully returned to the Chief of Ordnance, U. S. A.

Attention is invited to the accompanying four diagrams of targets made to-day at 500 yards from a fixed rest, with some of these cartridges taken from the daily product indiscriminately. A fresh breeze was blowing toward the targets in the direction of the line of fire. They are the best targets on record here with this ammunition.

S. C. LYFORD,
*Major of Ordnance, Commanding.*

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NATIONAL ARMORY, SPRINGFIELD, MASS.,
*April* 5, 1881.

SIR: In compliance with your instructions to test the cartridges lately received from Frankford Arsenal, loaded with both 70 and 80 grains powder, the former being hardened with tin in the proportion of $\frac{1}{12}$ and $\frac{1}{17}$, and having also flat and round points, I have the honor to submit the following report:

As it was understood that this was a reopening of the questions considered in my report of June 22, 1880, I have compiled from that report all relating to the Frankford bullet (500 grains, round point) showing the accuracy of that bullet when hardened by $\frac{1}{12}$ and $\frac{1}{17}$ tin. A summary will be found of what is given, all powders being classed as one, from which it will be seen the $\frac{1}{17}$ bullet proved the more satisfactory although the difference was but slight.

The results obtained at the various ranges with the Springfield hand-made bullet of $\frac{1}{12}$ and $\frac{1}{16}$ tin are also shown, which are in accordance with what has been said of the Frankford bullet; and results of trials with flat-pointed bullets with various proportions of tin. By a comparison of these results with the former it will be seen that the round-pointed bullet, hardened by $\frac{1}{16}$ tin, gave better accuracy than any other tried. It was therefore recommended for trial in the field. I now have to submit the results obtained with the cartridges which were the special subject of trial. It is necessary, however, to remark that a variety of guns of different weights of barrel, styles of rifling, &c., were undergoing trial at the same time, so that for the purpose of comparing the cartridges the guns must be classed as one. Summaries of these results at 500 and 800 yards are given, and the corresponding daily record.

From these summaries it will be seen that with the service rifle with peep and globe sights, at 500 yards, there was practically no difference in all the cartridges, the flat $\frac{1}{12}$ and round $\frac{1}{17}$ having exactly the same average—the flat $\frac{1}{17}$ 0''.4 greater and round $\frac{1}{12}$ 0''.4 less; while with the service rifle with service sights the order was: flat $\frac{1}{17}$, flat $\frac{1}{12}$, round $\frac{1}{12}$, and round $\frac{1}{17}$, the difference being trifling. An examination, however, of the daily record shows that four of the targets with the latter bullet were made late in the day, when it was quite dark, and when the marksmen were wearied with a whole day's firing, so that these targets are not quite up to the standard of those made earlier.

The average of all targets with both guns is the same for the flat $\frac{1}{12}$ and $\frac{1}{17}$ and round $\frac{1}{12}$, the round $\frac{1}{17}$ being about 0''.8 greater.

The 800 yards summary shows comparative performance of the 80 and 70 grains cartridges in long-chambered guns, and the various 70-grain cartridges in the service guns. From this summary it appears that 80 and 70 grains give equally good results in the long-chambered as do flat and round points $\frac{1}{12}$ and $\frac{1}{17}$ with 70 grains in the service guns. From this it appears that no change is necessary in the form or composition of the bullet now being prepared for trial in the field.

The Frankford bullet of last year was a very different one from that now being made, in diameter, length of cylindrical part, &c.

No leading occurred with the Springfield bullet, the diameter of which was two and a half thousandths less than the Frankford, and which was $\frac{1}{16}$ tin. This whole matter of leading is simply a bugbear which need trouble no one, and which does not affect shooting unless abnormal, a condition which never obtains with a reasonably good lubricant. The fact that the 70-grain cartridge may be used in the long-range guns with good results is important, and should go far to satisfy those marksmen who desire to change the powder-charge for every range.

Very respectfully, your obedient servant,

JOHN E. GREER,
*Captain of Ordnance, U. S. A.*

To the COMMANDING OFFICER NATIONAL ARMORY.

[From report of June 22, 1880.]

*Summary of result of firing at* 1,000 *yards.*

| Rifle. | Weight of powder. | Bullet. | | | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|
| | | Weight. | Caliber. | Frankford. | | | |
| | *Grs.* | *Grs.* | | | | | |
| Service | 70 | 500 | .458 | Round point | 31 | 29.3 | Bullet $\frac{1}{16}$ tin. |
| | | | | | 30 | 29.1 | Bullet $\frac{1}{17}$ tin. |
| 18-inch twist; 3 grooves | 70 | 500 | .458 | ....do | 4 | 28.2 | Bullet $\frac{1}{16}$ tin. |
| | | | | | 2 | 29.4 | Bullet $\frac{1}{17}$ tin. |
| Service; long chamber | 80 | 500 | .458 | ....do | 30 | 27.9 | Bullet $\frac{1}{16}$ tin. |
| | | | | | 16 | 28.9 | Bullet $\frac{1}{17}$ tin. |

800 *yards.*

| Rifle. | Weight of powder. | Weight. | Caliber. | Frankford. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|
| Service; long chamber | 80 | 500 | .458 | Round point | 16 | 19.3 | Bullet $\frac{1}{16}$ tin. |
| | | | | | 4 | 16.3 | Bullet $\frac{1}{17}$ tin. |

500 *yards.*

| Rifle. | Weight of powder. | Weight. | Caliber. | Frankford. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|
| Service | 70 | 500 | .458 | Round point | 33 | 10.4 | Bullet $\frac{1}{16}$ tin. |
| | | | | | 12 | 10.2 | Bullet $\frac{1}{17}$ tin. |
| Service; long chamber | 80 | 500 | .458 | ....do | 33 | 11.0 | Bullet $\frac{1}{16}$ tin. |
| | | | | | 14 | 10.8 | Bullet $\frac{1}{17}$ tin. |
| 18-inch twist; 6 grooves, long chamber. | 80 | 500 | .458 | ....do | 2 | 12.1 | Bullet $\frac{1}{16}$ tin. |

300 *yards.*

| Rifle. | Weight of powder. | Weight. | Caliber. | Frankford. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|
| Service | 70 | 500 | .458 | Round point | 7 | 4.9 | Bullet $\frac{1}{16}$ tin. |
| | | | | | 8 | 5.1 | Bullet $\frac{1}{17}$ tin. |
| Service; long chamber | 80 | 500 | .458 | ....do | 19 | 5.8 | Bullet $\frac{1}{16}$ tin. |
| | | | | | 4 | 5.4 | Bullet $\frac{1}{17}$ tin. |

1,000 *yards.*

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Kind. | | | |
| | *Grains.* | | *Grains.* | | | | | |
| Service rifle | 70 | Hazard, F. G. | 500 | .458 | Frankford, round point. | 19 | 29.1 | Bullet $\frac{1}{16}$ tin. |
| Do | 70 | ....do | 500 | .458 | ....do | 18 | 30.5 | Bullet $\frac{1}{17}$ tin. |
| Do | 70 | Oriental | 500 | .458 | ....do | 12 | 29.6 | Bullet $\frac{1}{16}$ tin. |
| Do | 70 | .. do | 500 | .458 | ....do | 12 | 26.9 | Bullet $\frac{1}{17}$ tin. |
| 18-inch twist, 3 grooves. | 70 | Hazard, F. G. | 500 | .458 | ....do | 2 | 26.0 | Bullet $\frac{1}{16}$ tin. |
| Do | 70 | ....do | 500 | .458 | ....do | 2 | 29.4 | Bullet $\frac{1}{17}$ tin. |
| Do | 70 | Dupont | 500 | .458 | ....do | 2 | 30.3 | Bullet $\frac{1}{16}$ tin. |
| Service rifle, long chamber. | 80 | Hazard, F. G. | 500 | .458 | ....do | 16 | 26.5 | do. |
| Do | 80 | ... do | 500 | .458 | ....do | 7 | 32.1 | Bullet $\frac{1}{17}$ tin. |
| Do | 80 | Oriental | 500 | .458 | ....do | 10 | 30.5 | Bullet $\frac{1}{16}$ tin. |
| Do | 80 | ... do | 500 | .458 | ....do | 9 | 26.5 | Bullet $\frac{1}{17}$ tin. |
| Do | 75 | Dupont | 500 | .458 | ....do | 5 | 25.2 | Bullet $\frac{1}{16}$ tin. |
| Do | 80 | ....do | 500 | .458 | ....do | 4 | 27.1 | do. |

### 800 *yards.*

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Springfield. | | | |
| | *Grains.* | | *Grains.* | | | | | |
| Service rifle, long chamber. | 75 | Dupont... ... | 500 | .458 | Frankford, round point. | 14 | 17.0 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 80 | ...do ......... | 500 | .458 | ....do ............... | 10 | 20.5 | do. |
| Do ...... | 80 | Hazard, F. G.. | 500 | .458 | ....do ............... | 6 | 17.4 | do. |
| Do ...... | 80 | ....do ......... | 500 | .458 | ... do ............... | 4 | 16.3 | Bullet $\frac{1}{17}$ tin. |

### 500 *yards.*

| Rifle. | Powder weight. | Powder kind. | Bullet weight. | Caliber. | Springfield. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Service ...... | 70 | Hazard, F. G.. | 500 | .458 | Frankford, round point. | 6 | 10.2 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 70 | ....do ......... | 500 | .458 | ... do ............... | 8 | 9.5 | Bullet $\frac{1}{17}$ tin. |
| Do ...... | 70 | Dupont ....... | 500 | .458 | ... do ............... | 4 | 12.8 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 70 | Oriental ...... | 500 | .458 | ....do ............... | 6 | 9.1 | do. |
| Do ...... | 70 | ....do ......... | 500 | .458 | ....do ............... | 4 | 11.6 | Bullet $\frac{1}{17}$ tin. |
| Service rifle, long chamber. | 80 | ....do ........ | 500 | .458 | ....do ............... | 9 | 12.2 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 80 | ....do ......... | 500 | .458 | ....do ............... | 5 | 10.4 | Bullet $\frac{1}{17}$ tin. |
| Do ...... | 80 | Hazard, F. G.. | 500 | .458 | ....do ............... | 12 | 10.1 | Bullet $\frac{1}{13}$ tin. |
| Do ...... | 80 | ....do ......... | 500 | .458 | ....do ............... | 9 | 11.0 | Bullet $\frac{1}{17}$ tin. |
| Do ...... | 80 | Dupont ....... | 500 | .458 | ....do ............... | 12 | 11.0 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 75 | ....do ......... | 500 | .458 | ....do ............... | 16 | 10.5 | do. |
| 18-inch twist, 6 grooves, long chamber. | 80 | Hazard, F. G.. | 500 | .458 | ....do ............... | 2 | 12.1 | do. |

### 300 *yards.*

| Rifle. | Powder weight. | Powder kind. | Bullet weight. | Caliber. | Springfield. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Service rifle.. | 70 | Hazard, F. G.. | 500 | .458 | Frankford, round point. | 4 | 4.0 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 70 | ....do ......... | 500 | .458 | ....do ............... | 4 | 5.1 | Bullet $\frac{1}{17}$ tin. |
| Do ...... | 70 | Oriental ...... | 500 | .458 | ....do ............... | 3 | 6.1 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 70 | ....do ......... | 500 | .458 | ....do ............... | 4 | 5.1 | Bullet $\frac{1}{17}$ tin. |
| Service rifle, long chamber. | 80 | Hazard, F. G.. | 500 | .458 | ....do ............... | 7 | 5.5 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 80 | ... do ......... | 400 | .458 | ....do ............... | 3 | 4.7 | Bullet $\frac{1}{17}$ tin. |
| Do ...... | 80 | Oriental ...... | 500 | .458 | ....do ............... | 3 | 6.1 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 80 | ....do ......... | 500 | .458 | ....do ............... | 1 | 7.6 | Bullet $\frac{1}{17}$ tin, |
| Do ...... | 80 | Dupont ....... | 500 | .458 | ....d5 ............... | 9 | 5.9 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 75 | ....do ......... | 500 | .458 | ....do ............... | 3 | 4.8 | do. |

### 1,000 *yards.*

| Rifle. | Powder weight. | Powder kind. | Bullet weight. | Caliber. | Springfield. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Service rifle.. | 70 | Hazard, F. G.. | 500 | .4555 | Round point ........ | 19 | 27.4 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 70 | ... do ......... | 500 | .4555 | ....do ............... | 43 | 24.9 | Bullet $\frac{1}{12}$ tin. |
| 18-inch twist; 3 grooves. | 70 | ....do ......... | 500 | .4555 | ....do ............... | 2 | 25.0 | Bullet $\frac{1}{12}$ tin. |
| Service rifle; long chamber. | 80 | ....do ......... | 500 | .4555 | ....do ............... | 21 | 21.5 | Bullet $\frac{1}{12}$ tin. |
| Do ...... | 80 | ....do ......... | 500 | .4555 | ....do ............... | 18 | 24.2 | Bullet $\frac{1}{12}$ tin. |

### 800 *yards.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Springfield. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | *Grains.* | | *Grains.* | | | | | |
| Service rifle.. | 70 | Hazard, F. G.. | 500 | .4555 | Round point ........ | 3 | 14.9 | Bullet $\frac{1}{16}$ tin. |
| Service rifle; long chamber. | 80 | ....do ......... | 500 | .4555 | ....do ............... | 8 | 16.3 | do. |
| Do ...... | 80 | ....do ......... | 500 | .4555 | ....do ............... | 4 | 18.2 | Bullet $\frac{1}{16}$ tin. |
| 18-inch twist; 6 grooves, long chamber. | 80 | ....do ......... | 500 | .4555 | ....do ............... | 10 | 15.2 | Bullet $\frac{1}{16}$ tin. |

### 500 *yards.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Springfield. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Service rifle.. | 70 | Hazard, F. G.. | 500 | .4555 | Round point ........ | 39 | 9.6 | Bullet $\frac{1}{16}$ tin. |
| Do ...... | 70 | ....do ......... | 500 | .4555 | ....do ............... | 23 | 10.5 | Bullet $\frac{1}{16}$ tin. |
| 18-inch twist; 3 grooves. | 70 | ....do ......... | 500 | .4555 | ....do ............... | 2 | 9.5 | Bullet $\frac{1}{16}$ tin. |
| 18-inch twist; 6 grooves, long chamber. | 80 | ....do ......... | 500 | .4555 | ....do ............... | 10 | 8.0 | do. |
| Service rifle; long chamber. | 80 | ... do ......... | 500 | .4555 | ....do ............... | 65 | 8.1 | do. |
| Do ...... | 80 | ....do ......... | 500 | .4555 | ....do ............... | 32 | 8.5 | Bullet $\frac{1}{16}$ tin. |

### 300 *yards.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Springfield. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Service rifle.. | 70 | Hazard, F. G.. | 500 | .4555 | Round point ........ | 5 | 3.7 | Bullet $\frac{1}{16}$ tin. |
| Service rifle; long chamber. | 80 | ....do ......... | 500 | .4555 | ....do ............... | 4 | 4.6 | do. |
| 18-inch twist; 6 grooves, long chamber. | 80 | ....do ......... | 500 | .4555 | ....do ............... | 14 | 4.9 | do. |

### 1,000 *yards.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Springfield. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Service rifle.. | 70 | Hazard, F. G.. | 500 | .452 | Flat point, No. 1 .... | 1 | 28.4 | Bullet $\frac{1}{16}$ tin. |
| Do ...... | 70 | ....do ......... | 500 | .456 | Flat point, No. 2 .... | 2 | 24.6 | do. |
| Do ...... | 70 | ....do ......... | 500 | .456 | Flat base, flat point, No. 2. | 2 | 26.2 | Bullet $\frac{1}{16}$ tin. |
| 18-inch twist; 3 grooves. | 70 | ....do ......... | 500 | .452 | Flat point, No. 1.... | 1 | 30.3 | Bullet $\frac{1}{16}$ tin. |
| Do ...... | 70 | ....do ......... | 500 | .456 | Flat point, No. 2.... | 2 | 24.5 | do. |
| Do ...... | 70 | ....do ......... | 500 | .456 | Flat base, flat point, No. 2. | 2 | 24.3 | Bullet $\frac{1}{16}$ tin. |
| 18-inch twist; 6 grooves. | 70 | ... do ......... | 500 | .452 | Flat point, No. 1.... | 1 | 28.1 | Bullet $\frac{1}{16}$ tin. |
| Do ...... | 70 | ....do ......... | 500 | .456 | Flat point, No. 2.... | 2 | 27.3 | do. |
| Do ...... | 70 | ....do ......... | 500 | .456 | Flat base, flat point, No. 2. | 2 | 26.0 | Bullet $\frac{1}{16}$ tin. |

### 500 *yards.*

| Rifle. | Powder. Weight. | Powder. Kind. | Bullet. Weight. | Bullet. Caliber. | Bullet. Springfield. | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Service rifle.. | 70 | Hazard, F. G.. | 500 | .45 | Flat base, flat point, No. 1. | 1 | 13.5 | Bullet $\frac{1}{16}$ tin. |
| 18-inch twist; 3 grooves. | 70 | ....do ......... | 500 | .45 | ....do ............... | 1 | 10.3 | do. |
| 18-inch twist; 6 grooves. | 70 | ....do ......... | 500 | .45 | ....do ............... | 2 | 17.6 | do. |

*300 yards.*

| Rifle. | Powder. | | Bullet. | | | No. of targets. | Mean deviations. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | Weight. | Kind. | Weight. | Caliber. | Springfield. | | | |
| | *Grains.* | | *Grains.* | | | | | |
| Service rifle.. | 70 | Hazard, F. G.. | 490 | .456 | Flat base, flat point, No. 2. | 1 | 5.8 | Bullet 1/12 tin. |
| Do...... | 70 | ....do.......... | 500 | .456 | ....do................ | 1 | 5.2 | Bullet 1/16 tin. |
| Do...... | 70 | ....do.......... | 500 | .45 | Flat base, flat point, No. 1. | 1 | 14.2 | Bullet 1/12 tin. |
| Do...... | 70 | ....do.......... | 500 | .45 | ....do................ | 1 | 24.0 | Bullet 1/16 tin. |
| 18 inch twist; 3 grooves. | 70 | ....do.......... | 500 | .45 | ....do................ | 1 | 5.3 | Bullet 1/12 tin. |
| Do...... | 70 | ....do.......... | 500 | .45 | ....do................ | 1 | 6.2 | Bullet 1/16 tin. |
| Do...... | 70 | ....do.......... | 500 | .456 | Flat base, flat point, No. 2. | 1 | 8.6 | do. |
| 18-inch twist; 6 grooves. | 70 | ....do.......... | 500 | .45 | Flat base, flat point, No. 1. | 1 | 14.0 | Bullet 1/12 tin. |
| Do...... | 70 | ....do.......... | 500 | .456 | Flat base, flat point, No. 2. | 1 | 4.2 | Bullet 1/12 tin. |

*Summary of results of firing at 800 yards.*

[The first nine guns have long chambers.]

| Rifle. | Sight. | Powder. | | Bullet. | | | No. of targets. | M. A. deviations. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Weight. | Kind. | Weight. | Caliber. | Kind. | | Flat point. | | Round point. | |
| | | | | | | | | 1/16 tin. | 1/12 tin. | 1/16 tin. | 1/12 tin. |
| | | *Grs.* | | *Grs.* | | | | | | | |
| No. 1. Springfield, special | Peep and globe; Sharps' | 80 | Unknown | 500 | .4555 | Frankford | 1 | ...... | ...... | ...... | 16.8 |
| | | | | | | | 2 | ...... | ...... | ...... | 19.8 |
| | | | | | | | 3 | ...... | ...... | ...... | 9.8 |
| No. 2. Springfield, special | do | 80 | do | 500 | .4555 | do | 1 | ...... | ...... | ...... | 15.7 |
| | | | | | | | 2 | ...... | ...... | ...... | 14.3 |
| | | | | | | | 3 | ...... | ...... | ...... | 13.3 |
| No. 3. Springfield, special | do | 80 | do | 500 | .4555 | do | 1 | ...... | ...... | ...... | 12.5 |
| | | | | | | | 2 | ...... | ...... | ...... | 17.0 |
| | | | | | | | 3 | ...... | ...... | ...... | 13.5 |
| No. 4. Springfield, special | Peep and globe; Springfield | 80 | do | 500 | .4555 | do | 1 | ...... | ...... | ...... | 16.3 |
| | | | | | | | 2 | ...... | ...... | ...... | 20.0 |
| | | | | | | | 3 | ...... | ...... | ...... | 13.4 |
| No. 5. Springfield, long-range | Peep and globe; Bull's | 80 | do | 500 | .4555 | do | 1 | ...... | ...... | ...... | 22.7 |
| | | | | | | | 2 | ...... | ...... | ...... | 11.5 |
| | | | | | | | 3 | ...... | ...... | ...... | 18.0 |
| No. 6. Springfield, long-range | Peep and globe; Sharps' | 80 | do | 500 | .4555 | do | 1 | ...... | ...... | ...... | 21.5 |
| | | | | | | | 2 | ...... | ...... | ...... | 22.0 |
| | | | | | | | 3 | ...... | ...... | ...... | 21.2 |
| | | | | | | | 4 | ...... | ...... | ...... | 10.1 |
| No. 7. Springfield, long-range | Open service | 80 | do | 500 | .4555 | do | 1 | ...... | ...... | ...... | 12.4 |
| | | | | | | | 2 | ...... | ...... | ...... | 12.7 |
| | | | | | | | 3 | ...... | ...... | ...... | 13.3 |
| | | | | | | | 4 | ...... | ...... | ...... | 12.5 |
| No. 8. Service, long-chamber | Peep and globe; Sharps' | 80 | do | 500 | .4555 | do | 1 | ...... | ...... | ...... | 16.5 |
| | | | | | | | 2 | ...... | ...... | ...... | 26.6 |
| | | | | | | | 3 | ...... | ...... | ...... | 19.0 |
| No. 9. Service, long-chamber | Open service | 80 | do | 500 | .4555 | do | 1 | ...... | ...... | ...... | 26.6 |
| | | | | | | | 2 | ...... | ...... | ...... | 17.5 |
| | | | | | | | 3 | ...... | ...... | ...... | 17.6 |
| | | | | | | | Mean | ...... | ...... | ...... | 17.0 |
| No. 1. Springfield, special | Peep and globe; Sharps' | 70 | do | 500 | .4555 | do | 1 | 17.1 | 10.9 | 20.3 | 14.5 |
| No. 2. Springfield, special | do | 70 | do | 500 | .4555 | do | 1 | 14.3 | 11.5 | 14.2 | 18.3 |
| No. 3. Springfield, special | do | 70 | do | 500 | .4555 | do | 1 | 16.0 | 13.6 | 13.2 | 15.1 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 4. Springfield, special | Peep and globe; Springfield | 70 | ...do | 500 | .4555 | ...do | 1 | 12.5 | 14.5 | 11.7 | 18.8 |
| No. 5. Springfield, long-range | Peep and globe; Bull's | 70 | ...do | 500 | .4555 | ...do | 1 | 12.1 | 14.6 | 10.6 | 12.8 |
| | | | | | | | 2 | 19.9 | 17.0 | 17.6 | 17.0 |
| No. 6. Springfield, long-range | Peep and globe; Sharps' | 70 | ...do | 500 | .4555 | ...do | 1 | 14.7 | 17.8 | 20.6 | 19.2 |
| | | | | | | | 2 | 23.0 | 22.9 | 10.8 | 13.7 |
| No. 7. Springfield, long-range | Open service | 70 | ...do | 500 | .4555 | ...do | 1 | 17.8 | 11.6 | 17.8 | 19.2 |
| | | | | | | | 2 | 23.2 | 17.5 | 15.8 | 23.6 |
| No. 8. Service, long-chamber | Peep and globe; Sharps' | 70 | ...do | 500 | .4555 | ...do | 1 | 16.8 | 19.4 | 20.1 | 17.5 |
| No. 9. Service, long-chamber | Open service | 70 | ...do | 500 | .4555 | ...do | 1 | 15.5 | 18.2 | 16.5 | 19.9 |
| | | | | | | | Mean | 16.9 | 15.4 | 15.8 | 17.4 |
| No. 10. Service | Peep and globe; Sharps' | 70 | ...do | 500 | .4555 | ...do | 1 | ...... | ...... | ...... | 18.3 |
| | | | | | | | 2 | ...... | ...... | ...... | 18.5 |
| | | | | | | | 3 | ...... | ...... | ...... | 9.5 |
| | | | | | | | 4 | 15.2 | 21.7 | 12.6 | 16.1 |
| | | | | | | | 5 | 15.0 | 14.5 | 14.8 | 17.5 |
| | | | | | | | 6 | ...... | ...... | 17.4 | 16.8 |
| No. 11. Service | Open service | 70 | ...do | 500 | .4555 | ...do | 1 | ...... | ...... | ...... | 25.1 |
| | | | | | | | 2 | ...... | ...... | ...... | 15.8 |
| | | | | | | | 3 | ...... | ...... | ...... | 12.7 |
| | | | | | | | 4 | 20.7 | 15.2 | 17.6 | 18.8 |
| | | | | | | | 5 | 14.9 | 16.9 | 23.8 | 17.0 |
| | | | | | | | 6 | ...... | ...... | 13.5 | 23.7 |
| | | | | | | | Mean | 16.4 | 17.1 | 16.5 | 16.9 |

*Summary of results of firing at 500 yards.*

[The first nine guns have long chambers.]

| Rifle. | Sight. | Powder. | | Bullet. | | | No. of targets. | M. A. deviations. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Flat point. | | Round point. | | |
| | | Weight. | Kind. | Weight. | Caliber. | Kind. | | 1/13 tin. | 1/17 tin. | 1/13 tin. | 1/17 tin. | |
| | | *Grs.* | | *Grs.* | | | | | | | | |
| No. 1. Springfield, special | Peep and globe; Sharps' | 80 | Unknown | 500 | .4555 | Frankford | 1 | ... | ... | ... | 5.2 | Fired as nearly as possible under the circumstances. |
| | | | | | | | 2 | ... | ... | ... | 6.7 | |
| | | | | | | | 3 | ... | ... | ... | 6.7 | |
| No. 2. Springfield, special | do | 80 | do | 500 | .4555 | do | 1 | ... | ... | ... | 7.6 | |
| | | | | | | | 2 | ... | ... | ... | 7.6 | |
| | | | | | | | 3 | ... | ... | ... | 8.7 | |
| No. 3. Springfield, special | do | 80 | do | 500 | .4555 | do | 1 | ... | ... | ... | 7.6 | |
| | | | | | | | 2 | ... | ... | ... | 6.7 | |
| No. 4. Springfield, special | Peep and globe; Springfield | 80 | do | 500 | .4555 | do | 1 | ... | ... | ... | 5.0 | |
| | | | | | | | 2 | ... | ... | ... | 4.8 | |
| No. 5. Springfield, long-range | Peep and globe; Bull's | 80 | do | 500 | .4555 | do | 1 | ... | ... | ... | 11.0 | |
| | | | | | | | 2 | ... | ... | ... | 4.3 | |
| | | | | | | | 3 | ... | ... | ... | 8.0 | |
| | | | | | | | 4 | ... | ... | ... | 11.6 | |
| No. 6. Springfield, long-range | Peep and globe; Sharps' | 80 | do | 500 | .4555 | do | 1 | ... | ... | ... | 6.0 | |
| | | | | | | | 2 | ... | ... | ... | 8.7 | |
| | | | | | | | 3 | ... | ... | ... | 5.2 | |
| | | | | | | | 4 | ... | ... | ... | 8.9 | |
| | | | | | | | 5 | ... | ... | ... | 8.0 | |
| | | | | | | | 6 | ... | ... | ... | 8.4 | |
| | | | | | | | 7 | ... | ... | ... | 6.5 | |
| | | | | | | | 8 | ... | ... | ... | 7.9 | |
| | | | | | | | 9 | ... | ... | ... | 5.8 | |
| No. 7. Springfield, long-range | Open service | 80 | do | 500 | .4555 | do | 1 | ... | ... | ... | 7.6 | |
| | | | | | | | 2 | ... | ... | ... | 6.4 | |
| | | | | | | | 3 | ... | ... | ... | 6.6 | |
| | | | | | | | 4 | ... | ... | ... | 9.9 | |
| | | | | | | | 5 | ... | ... | ... | 7.4 | |
| | | | | | | | 6 | ... | ... | ... | 9.0 | |
| | | | | | | | 7 | ... | ... | ... | 7.6 | |
| | | | | | | | 8 | ... | ... | ... | 5.9 | |
| | | | | | | | 9 | ... | ... | ... | 8.9 | |
| No. 8. Service, long-chamber | Peep and globe; Sharps' | 80 | do | 500 | .4555 | do | 1 | ... | ... | ... | 9.5 | |
| | | | | | | | 2 | ... | ... | ... | 10.8 | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 9. Service, long-chamber | Open service | 80 | do | 500 | .4555 | do | 1 | | | | 14.9 |
| | | | | | | | 2 | | | | 7.8 |
| | | | | | | | 3 | | | | 8.1 |
| | | | | | | | Mean | | | | 7.8 |
| No. 10. Service | Peep and globe; Sharps' | 70 | do | 500 | .4555 | do | 1 | | | | 8.1 |
| No. 11. Service | Service | 70 | do | 500 | .4555 | do | 1 | | | | 8.3 |
| | | | | | | | Mean | | | | 8.2 |
| No. 10. Service | Peep and globe; Sharps' | 70 | do | 500 | .4555 | do | 1 | 6.0 | 5.9 | 4.3 | 6.1 |
| | | | | | | | 2 | 5.7 | 4.8 | 6.4 | 5.0 |
| | | | | | | | 3 | 5.5 | 6.6 | 4.4 | 7.6 |
| | | | | | | | 4 | 5.8 | 7.2 | 5.8 | 3.4 |
| | | | | | | | 5 | 5.6 | 5.4 | 5.8 | 5.4 |
| | | | | | | | 6 | | 6.5 | | 6.9 |
| | | | | | | | Mean | 5.7 | 6.1 | 5.3 | 5.7 |
| No. 11. Service | Open service | 70 | do | 500 | .4555 | do | 1 | 6.4 | 6.0 | 6.1 | 5.6 |
| | | | | | | | 2 | 5.1 | 5.8 | 6.0 | 8.8 |
| | | | | | | | 3 | 6.6 | 5.2 | 6.2 | 7.3 |
| | | | | | | | 4 | 5.1 | 6.6 | 6.9 | 8.4 |
| | | | | | | | 5 | 6.6 | 6.1 | 6.4 | 8.7 |
| | | | | | | | 6 | | 4.5 | | 7.7 |
| | | | | | | | Mean | 6.0 | 5.7 | 6.3 | 7.7 |
| | | | | | | Mean of both service guns | | 5.9 | 5.9 | 5.8 | 6.7 |

500 *yards range.—March* 14, 1881.

[Five targets previously made with 80 grains.]

| Rifle. | Sight. | Weight of powder. | Bullet. Weight. | Bullet. Proportion of tin. | Bullet. Frankford. | Mean deviation. | By whom fired. |
|---|---|---|---|---|---|---|---|
| | | Grs. | Grs. | | | | |
| No. 10. Service | Peep and globe; Sharp's. | 70 | 500 | 1/16 | Flat point | 6.0 | Bull. |
| No. 11. Service | Open service | 70 | 500 | 1/16 | ....do | 6.4 | Hare. |

Four targets now made with 80 grains.

| Rifle. | Sight. | Weight of powder. | Bullet. Weight. | Bullet. Proportion of tin. | Bullet. Frankford. | Mean deviation. | By whom fired. |
|---|---|---|---|---|---|---|---|
| No. 11. Service | Open service | 70 | 500 | 1/16 | Round point. | 6.1 | Bull. |
| No. 10. Service | Peep and globe; Sharps' | 70 | 500 | 1/16 | ....do | 4.3 | Hare. |
| No. 10. Service | ......do | 70 | 500 | 1/17 | Flat point | 5.9 | Bull. |
| No. 11. Service | Open service | 70 | 500 | 1/17 | ....do | 6.0 | Hare. |
| No. 11. Service | ......do | 70 | 500 | 1/17 | ....do | 5.8 | Bull. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | 1/17 | ....do | 6.6 | Hare. |

Five targets now made with 80 grains. Strong breeze from left and rear.

500 *yards range.—March* 15, 1881.

[Eight targets previously made with 80 grains.]

| Rifle. | Sight. | Weight of powder. | Bullet. Weight. | Bullet. Proportion of tin. | Bullet. Frankford. | Mean deviation. | By whom fired. |
|---|---|---|---|---|---|---|---|
| | | Grs. | Grs. | | | | |
| No. 11. Service | Open service | 70 | 500 | 1/17 | Round point. | 5.6 | Hare. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | 1/17 | ....do | 6.1 | Bull. |
| No. 10. Service | ......do | 70 | 500 | 1/17 | ....do | 5.0 | Hare. |
| No. 11. Service | Open service | 70 | 500 | 1/17 | ....do | 8.8 | Bull. |
| No. 11. Service | ......do | 70 | 500 | 1/17 | Flat point | 5.2 | Hare. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | 1/17 | ....do | 4.8 | Bull. |
| No. 10. Service | ......do | 70 | 500 | 1/17 | ....do | 7.2 | Hare. |
| No. 11. Service | Open service | 70 | 500 | 1/17 | ....do | 6.6 | Bull. |
| No. 11. Service | ......do | 70 | 500 | 1/16 | ....do | 5.1 | Hare. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | 1/16 | ....do | 5.7 | Bull. |
| No. 10. Service | ......do | 70 | 500 | 1/16 | ....do | 5.5 | Hare. |
| No. 11. Service | Open service | 70 | 500 | 1/16 | ....do | 6.6 | Bull. |
| No. 11. Service | ......do | 70 | 500 | 1/16 | Round point. | 6.0 | Hare. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | 1/16 | ....do | 6.4 | Bull. |
| No. 10. Service | ......do | 70 | 500 | 1/16 | ....do | 4.4 | Hare. |
| No. 11. Service | Open service | 70 | 500 | 1/17 | ....do | 6.2 | Bull. |
| No. 11. Service | ......do | 70 | 500 | 1/17 | ....do | 7.3 | Hare. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | 1/17 | ....do | 7.6 | Bull. |
| No. 10. Service | ......do | 70 | 500 | 1/17 | ....do | 3.4 | Hare. |
| No. 11. Service | Open service | 70 | 500 | 1/17 | ....do | 8.4 | Bull. |

Strong wind from the left during the day; last four targets very dark.

500 *yards.—March* 16, 1881.

| Rifle. | Sight. | Weight of powder. | Bullet. Weight. | Bullet. Proportion of tin. | Bullet. Frankford. | Mean deviation. | By whom fired. |
|---|---|---|---|---|---|---|---|
| | | *Grs.* | *Grs.* | | | | |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{16}$ | Flat point | 5.8 | Hare. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{16}$ | ....do | 5.1 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{16}$ | ....do | 5.6 | do. |
| No. 11. Service | Open service | 70 | 500 | ..... | ....do | 6.6 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 5.4 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 6.1 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 6.5 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 4.5 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | Round point. | 5.8 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{16}$ | ....do | 6.9 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{16}$ | ....do | 5.8 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{16}$ | ....do | 6.4 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 5.4 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 8.7 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 6.9 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 7.7 | do. |

Very strong wind from the left.

800 *yards.—March* 21, 1881.

| Rifle. | Sight. | Weight of powder. | Bullet. Weight. | Bullet. Proportion of tin. | Bullet. Frankford. | Mean deviation. | By whom fired. |
|---|---|---|---|---|---|---|---|
| | | *Grs.* | *Grs.* | | | | Hare. |
| No. 1. Springfield; special | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{16}$ | Flat point | 17.1 | do. |
| No. 2. Springfield; special | ......do | 70 | 500 | $\frac{1}{16}$ | ....do | 14.3 | do. |
| No. 3. Springfield; special | ......do | 70 | 500 | $\frac{1}{16}$ | ....do | 16.0 | do. |
| No. 4. Springfield; special | Peep and globe; Springfield. | 70 | 500 | $\frac{1}{16}$ | ....do | 12.5 | do. |
| No. 5. Springfield; long-range | Peep and globe; Bulls'. | 70 | 500 | $\frac{1}{16}$ | ....do | 12.1 | do. |
| No. 6. Springfield; long-range | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{16}$ | ....do | 14.7 | do. |
| No. 7. Springfield; long-range | Open service | 70 | 506 | $\frac{1}{16}$ | ....do | 17.8 | do. |
| No. 8. Service; long-chamber. | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{16}$ | ....do | 16.3 | do. |
| No. 9. Service; long-chamber. | Open service | 70 | 500 | $\frac{1}{16}$ | ....do | 16.5 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{16}$ | ....do | 15.2 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{16}$ | ....do | 20.7 | do. |
| No. 1. Springfield; special | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 10.9 | do. |
| No. 2. Springfield; special | ......do | 70 | 500 | $\frac{1}{17}$ | ....do | 11.5 | do. |
| No. 3. Springfield; special | ......do | 70 | 500 | $\frac{1}{17}$ | ....do | 13.6 | do. |
| No. 4. Springfield; special | Peep and globe; Springfield. | 70 | 500 | $\frac{1}{17}$ | ....do | 14.5 | do. |
| No. 5. Springfield; long-range | Peep and globe; Bulls'. | 70 | 500 | $\frac{1}{17}$ | ....do | 14.6 | do. |
| No. 6. Springfield; long-range | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 17.8 | do. |
| No. 7. Springfield; long-range | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 11.6 | do. |
| No. 8. Service; long-chamber. | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 19.4 | do. |
| No. 9. Service; long-chamber. | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 13.2 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 21.7 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 15.2 | do |

Strong wind from the right and rear.

800 *yards range.—March* 22, 1881.

| Rifle. | Sight. | Weight of powder. | Bullet. Weight. | Bullet. Proportion of tin. | Bullet. Frankford. | Mean deviation. | By whom fired. |
|---|---|---|---|---|---|---|---|
| | | *Grs.* | *Grs.* | | | | |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | Round point | 16.1 | Hare. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 18.8 | do. |
| No. 6. Springfield; long-range | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 19.2 | do. |
| No. 7. Springfield; long-range | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 19.2 | do. |
| No. 2. Springfield; special | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 18.3 | do. |
| No. 3. Springfield; special | ......do | 70 | 500 | $\frac{1}{17}$ | ....do | 15.1 | do. |
| No. 4. Springfield; special | Peep and globe; Springfield. | 70 | 500 | $\frac{1}{17}$ | ....do | 18.8 | do. |
| No. 5. Springfield; long-range | Peep and globe; Bulls'. | 70 | 500 | $\frac{1}{17}$ | ....do | 12.3 | do. |
| No. 1. Springfield; special | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 14.5 | do. |
| No. 8. Service; long-chamber. | ......do | 70 | 500 | $\frac{1}{17}$ | ....do | 17.5 | do. |
| No. 9. Service; long-chamber. | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 19.9 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 12.6 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 17.6 | do. |
| No. 6. Springfield; long-range | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 20.6 | do. |
| No. 7. Springfield; long-range | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 17.8 | do. |
| No. 2. Springfield; special | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 14.2 | do. |
| No. 3. Springfield; special | ......do | 70 | 500 | $\frac{1}{17}$ | ....do | 13.3 | do. |
| No. 4. Springfield; special | Peep and globe; Springfield. | 70 | 500 | $\frac{1}{17}$ | ....do | 11.7 | do. |
| No. 5. Springfield; long-range | Peep and globe; Bulls'. | 70 | 500 | $\frac{1}{17}$ | ....do | 10.6 | do. |
| No. 1. Springfield; special | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 20.3 | do. |
| No. 8. Service; long-chamber. | ......do | 70 | 500 | $\frac{1}{17}$ | ....do | 20.2 | do. |
| No. 9. Service; long-chamber. | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 16.5 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 14.3 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 23.3 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 17.5 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 17.0 | do. |

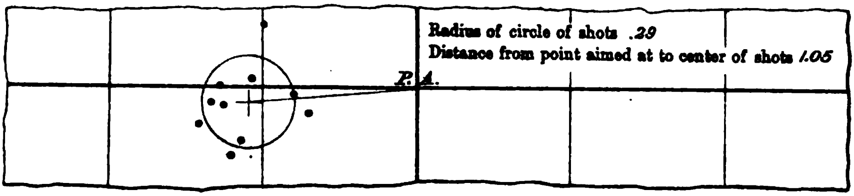
Fresh breeze from left and front.

800 *yards range.—March* 23, 1881.

| Rifle. | Sight. | Weight of powder. | Bullet. Weight. | Bullet. Proportion of tin. | Bullet. Frankford. | Mean deviation. | |
|---|---|---|---|---|---|---|---|
| | | *Grs.* | *Grs.* | | | | |
| No. 6. Springfield; long-range | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | Flat point. | 23.0 | Hare. |
| No. 7. Springfield; long-range | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 23.2 | do. |
| No. 5. Springfield; long-range | Peep and globe; Bulls'. | 70 | 500 | $\frac{1}{17}$ | ....do | 19.9 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 15.0 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 14.9 | do. |
| No. 6. Springfield; long-range | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 22.9 | do. |
| No. 7. Springfield; long-range | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 17.5 | do. |
| No. 5. Springfield; long-range | Peep and globe; Bulls'. | 70 | 500 | $\frac{1}{17}$ | ....do | 17.0 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 14.5 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 16.9 | do. |
| No. 6. Springfield; long-range | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | Round point | 10.8 | do. |
| No. 7. Springfield; long-range | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 15.8 | do. |
| No. 5. Springfield; long-range | Peep and globe; Bulls'. | 70 | 500 | $\frac{1}{17}$ | ....do | 17.6 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 17.4 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 13.5 | do. |
| No. 6. Springfield; long-range | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 13.7 | do. |
| No. 7. Springfield; long-range | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 23.6 | do. |
| No. 5. Springfield; long-range | Peep and globe; Bulls'. | 70 | 500 | $\frac{1}{17}$ | ....do | 17.0 | do. |
| No. 10. Service | Peep and globe; Sharps'. | 70 | 500 | $\frac{1}{17}$ | ....do | 16.3 | do. |
| No. 11. Service | Open service | 70 | 500 | $\frac{1}{17}$ | ....do | 23.7 | do. |

Fresh breeze from the left and rear; last four targets strong wind and gusty.

## No. 1.

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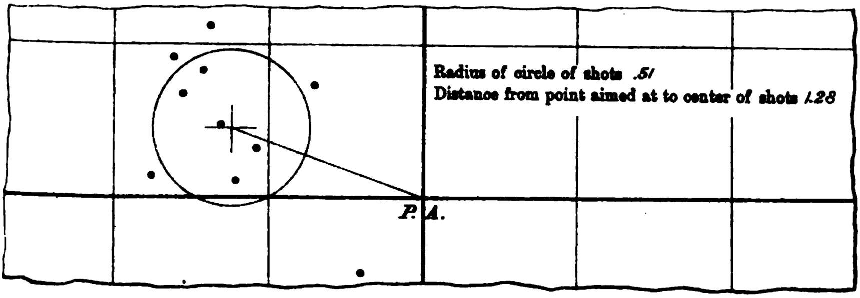


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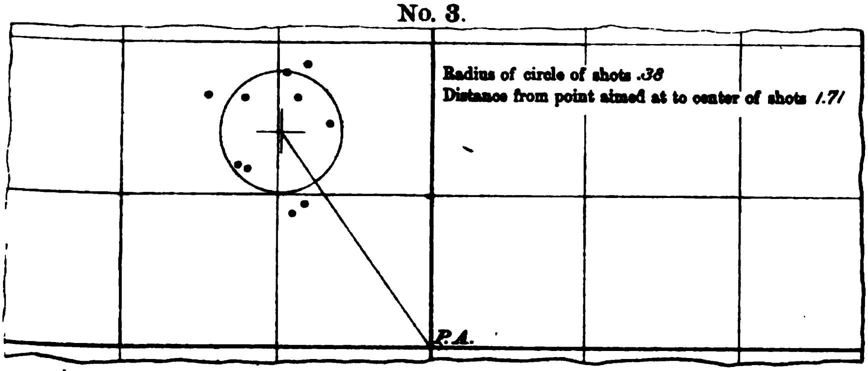


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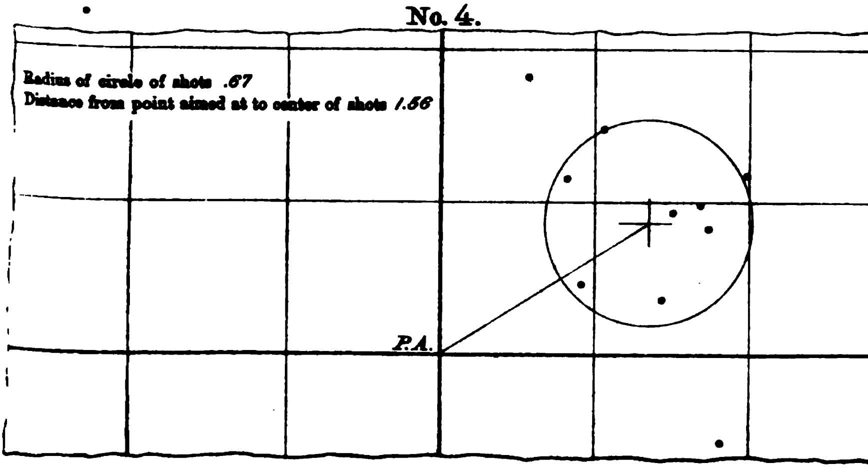



Size of Target 15 × 16 Feet. Distance of Target 500 Yards.

Appendix 28—1881.

## APPENDIX 29.

### A REPORT ON PRISM RANGE-FINDERS.

BY LIEUT. A. H. RUSSELL, UNDER THE DIRECTION OF COL. T. T. S. LAIDLEY, ORDNANCE DEPARTMENT.

(One plate.)

SIR: I have the honor to make the following report on the prism range-finders submitted to me by the Chief of Ordnance in the fourth indorsement, April 11, 1881, on my letter of December 14, 1880.

The three prisms are herewith returned, viz:

1. The original Weldon range-finder from London.
2. The modified Weldon range-finder described in Ordnance Notes 134.
3. The six-sided prism proposed in the above letter.

The first was found to be valueless, as it does not give constant angles.

The second operated as described in Ordnance Notes 134, and it was found to be subject to the same inconveniences as were there mentioned—the necessity for taking a back sight in observation, and its limitations in a single base.

The third, or six-sided prism, has been modified as follows: The top and bottom surfaces have been ground, and the bevel on the edges has been thereby almost removed, so as to offer but slight interference with vision. The cover has been removed, as it obstructed the light, and the reflected image can now be brought into close contact with the object seen by direct vision. In addition to this the apertures have been enlarged so that observations can be made at all the angles without inverting the instrument. Small clamps projecting from the sides hold the glass in place without interfering with the observation. A ring has been added for suspending it to the neck if desired, and a small leather pouch is provided for convenience in carrying.

Fig. 1 shows the instrument in perspective. A is the prism, B the frame; *a*, *b*, *c*, *d*, and *e* are the apertures for observation; *l*, *l*, *l*, the clamps which retain the prism in place; and *m* is the ring to which the string may be attached. Near each aperture is shown an arrow-mark to indicate approximately the direction in which the observer should look into the prism. The aperture at *a* has two of these marks, the right-hand one for use in connection with the aperture *b* and the left-hand one with the aperture *c*. The aperture *e* is used in connection with *d*, *b* with *a*, and *c* also with *a*. A square, marked on the surface between the apertures *d* and *e*, indicates that they correspond to a right angle, and the acute-angle mark between the apertures *c* and *a* indicates their use together for laying off an acute angle. The apertures *a* and *b* are used together for laying off an obtuse angle. No handle is provided, but the instrument is to be grasped by the sides between the thumb and forefinger, usually

of the hand opposite the object seen by reflection. The tip of the finger should usually cover the aperture opposite to the one into which the observer is looking, in order to cut off colored rays which might interfere with clear vision. For instance, while looking through *a* and obtaining the reflection through *b*, the observer should cover *e*; and while obtaining the reflection through *c* he should cover *d*; while looking into *d* he should cover *a*, &c. The proper image to be selected is easily found, as it remains steady, while other images which may be seen move very quickly when the prism is turned horizontally. The principles of reflection are the same as for the Weldon prism.

The following description of the prism is, for convenience of reference, taken from a former letter: "Fig. 2 is a horizontal section of the prism. The faces A B and E D are parallel. The angle A is equal to the acute angle desired. B C makes with E D half the angle A, and C D makes with A B half the supplement of A. The angle C is 90°, and E F makes with A B an angle of 45°. Light following the course from I to J gives a deviation equal to A; that following the course from I′ to J′, a deviation equal to the supplement of A; and that from I″ to J″, a deviation of 90°. The parts shown in heavy lines are silvered, and all the portions bounded by double lines are covered by the frame."

* * * * * * *

"In obtaining the distance of the object C (Fig. 3), an observer at A lays off the angle C A E, obtaining the reflection of the object C with the acute angle of the prism, and at the same time looking over the prism in the direction of the base A E; then advancing along the line A E (without turning round) and using the obtuse angle, he stops when he reaches a point, B, where he sees the reflection of the object C in the direction of E." If the right angle be used the observer makes his first station at D and his second at A or B, as he can use either the acute or the obtuse angle in connection with the right angle. It is perhaps better to make the forward station first, as the observer can probably keep his alignment more readily by moving backward and so increasing his distance from the point sighted on. Where the whole base A B is used, multiplying it by 20 gives the distance; where half this base is used it should be multiplied by 40.

Careful measurements, with corrections for errors of observation, give the following values for the angles of the prism:

| Angles required. | Angles obtained by measurement. |
|---|---|
| A, 88° 34′ 3″ | 88° 34′ 5″ |
| B, 135° 42′ 58″.5 | 135° 43′ 50″ |
| C, 90° | 89° 59′ 20″ |
| D, 134° 17′ 1″.5 | 134° 17′ 20″ |
| E, 135° | 135° 0′ 20″ |
| F, 136° 25′ 57″ | 136° 25′ 5″ |

Notwithstanding these errors in the angles the results shown in the table were obtained by observations at Fort Monroe and Sandy Hook, in some cases the multiplier 20 being used and in others the multiplier 40, the latter case being of course more liable to error on account of the use

of a shorter base. The instrument can be used like the Weldon range-finder, by observing only with the acute angle, if desired.

| Distance. | Error. | Multiplier. |
|---|---|---|
| *Yards.* | *Yards.* | |
| 686 | + 7 | 20 |
| 752 | — 5 | " |
| 685.5 | + 8.5 | " |
| 686 | + 13 | 40 |
| 1,075 | — 50 | " |
| *1,822 | + 164 | " |
| 1,822 | + 98 | " |
| *1,933 | + 147 | " |
| 1,933 | + 27 | " |
| 2,918 | — 98 | " |

The greatest base used in these measurements was 73 yards, and usually it was not over 40 yards, while in the trials of the Watkin range-finder described in Ordnance Notes 116, the shortest base was 63 yards, and most of the bases exceeded 100 yards, the greatest being 128 yards. The longer the base used the greater the difficulty in finding the proper ground for observation.

As indicated in my letter of March 15, three triangular prisms might be substituted for the one six-sided prism, and with this arrangement the method of observation might be learned rather more readily, as there would be no need of covering up the apertures, while the field of view would be somewhat enlarged. Fig. 4 shows such an arrangement: A, B, and C are triangular prisms made on the Weldon principle—A for a right angle, B and C for acute and obtuse supplementary angles respectively. The frame D supports the three prisms. It is doubtful, however, if any real advantage would here obtain over the six-sided single-prism form.

Of the mirror telemeters giving fixed angles, that of Azémar, described in the report on telemeters submitted by me to the Ordnance Office in January last, seems to be the simplest. This was made to give two angles, one acute and the other obtuse, supplements of each other. It is shown in Figure 5 with the addition, suggested in the above-mentioned report, of an additional fixed mirror for giving a right angle. If only two angles are used, an acute combined with a right angle would be better than the two supplementary angles, as the advantage of having a right angle would be secured without necessitating back sights in observation.

The modified Azémar telemeter consists of a small frame, L M N, on which are placed four plane mirrors reaching from the top to the bottom of the frame; this frame swinging between two plates of brass, G K, it being pushed out and in by turning it about the pivot P. The mirrors L, Q, and M make with the mirror N angles less than, equal to, and greater than 90° respectively—the greatest and least angles being complements of each other. Such a telemeter commends itself by its cheapness, but a prism telemeter gives far greater clearness to the image, while, unlike the mirror telemeter, it is not subject to derangement.

* The first observations at the distances of 1,822 and 1,933 yards were made under inconvenient circumstances, when the sight was uncertain. The repetitious were more accurate.

The above experiments justify the recommendation in Ordnance Notes 134 of an arrangement for reflecting right angles in connection with another fixed angle like that in the Weldon instrument, and show also the advantage of having an additional angle supplementary to the acute angle. It will be useful for other than telemetric purposes for the officer to have the means of measuring a right angle, since it will be convenient for setting out perpendiculars, and will enable him to align himself between two points without depending on an assistant. In the use of the above telemeters an assistant is undoubtedly useful, but these instruments, which do not require back sights to be taken, are not so dependent as the others on such assistance.

It is proper to refer here to a paper by Col. A. W. Drayson, R. A., F. R. A. S., printed in the proceedings of the R. A. Institute for January, 1881. He says:

Having had an instrument constructed fifteen years ago, by Messrs. Troughton & Simms, identical with that which Major Weldon has lately invented, and having given both the instrument and the method a very extensive trial at Woolwich and Shoeburyness before committees, and at Aldershot, I consider it may be of some interest if I give the results of my experience connected therewith.

Finding that persons unused to instruments had some difficulty in setting the index of a sextant to any given angle—such as 84° 17′, 87° 8′, or 88° 34′—I consulted with Mr. Simms, of the firm of Troughton & Simms, as regards constructing a small instrument like an optical square, which should by reflection show these angles only. These opticians turned me out four instruments; one an optical square set to show 90° only, another to show 88° 34′, a third 87° 8′, and a fourth 84° 17′.

After a long series of trials I selected the optical square and the instrument showing 87° 8′, and I used these in the following manner:

The optical square was used to set off the right angle between the distant object and the second observer. The instrument showing 87° 8′ was used to place the second observer so that the distant object coincided in the object-glass of the instrument with the observer using the optical square. The range of the distant object was then 20 times the base.

The base may be placed if great accuracy is not required, but it ought to be measured.

For measuring I used a stout tape on a large roller, and when gunners or private soldiers used this an error in multiplying sometimes occurred. For example, suppose the base was 69 yards, I have been given the range as 1,280 yards instead of 1,380. To avoid this source of error I requested Messrs. Elliot, opticians, to construct for me stout tape, on which *half* yards were shown and numbered, so that a base 69 yards long would be shown on the tape and read as 138 *divisions*. No multiplication was then necessary, as the range was read off by annexing 0, and was given as 1,380 yards.

The first practical difficulty I encountered with this method was, that if the range should be as much as 4,000 yards the base must be 200 yards long, and to find a position for a base of such length was often impossible in inclosed country; or, if the base could be obtained, the distant object, the range of which was required, could not be seen from both ends of the base.

In order to have a choice of positions I usually carried the instrument showing 88° 34′, and when a base of 200 yards for a 4,000-yard range was not obtainable I used a base of half the length and the angle 88° 34′, when the range = base × 40.

Owing to obstacles, the nature of the ground, &c., I found that a fixed base of $\frac{1}{10}$, $\frac{1}{20}$, or $\frac{1}{40}$ the range was most inconvenient in rough country, and so I gave up this method in favor of that requiring a variable angle and any convenient base, the optical square being used as before to set off the right angle, and the pocket sextant being used to measure the acute angle—a table being used to read off the range.

After many years' practice in all countries I have found this method the best and most convenient. The errors, with competent observers, vary from 1 to 3 per cent., and the time occupied varies from 1 to 3 minutes.

Captain Everett, Thirty-third Regiment, who was my assistant at the Royal Military Academy, could with me find a range in less than 40 seconds, and with an error rarely more than one per cent., and such results were obtained before a committee at Shoeburyness.

In all these methods, however, it is necessary, from the principle of the instruments used, that the base should be horizontal, or nearly so. In hilly country this is almost impracticable, and great errors will result.

In order to obtain the full benefit of any range-finder, thoroughly competent observers must be employed. To hope that any method of range-finding can be used by men

who are unskilled is a delusion. So that it really seems desirable that there should be attached to each battery men trained as range-finders, receiving some small increase of pay when thus qualified.

We do not expect that every gunner should, after an hour's instruction, be competent to shoe a horse, and the value of knowing one's range so as not to waste ammunition is certainly of sufficient importance to demand training and attention.

The method of using the fixed angles and variable base, such as 88° 34′, 87° 8′, and 84° 17′, I taught at Hythe to the school of musketry, also at Aldershot, and at Woolwich about ten years ago; also, the more useful method of any angle and any base in order to overcome the defects of the fixed angle.

It will be seen from these facts that the Weldon range-finder is not quite a novelty, and from the supposed perfection of the instrument, and the method, it appears that its practical difficulties have not yet been discovered.

This opinion as to the difficulty of using fixed-angle telemeters is similar to that expressed in Ordnance Notes 134, though there are undoubtedly many cases where they would be very useful. It is thought that the method of use suggested by Lieut. Sedgwick Pratt, Third Artillery, U. S. A., may materially increase the value of fixed-angle telemeters. An outline of this method is here given as applied in general to telemeters with fixed angles. It enables the observer to obtain the distance between two points even when he can occupy neither of them.

The observer being at C, Fig. 6, to obtain the distance between the points A and B, he lays off the bases C C′ and C C″, as if to determine the distances C A and C B, respectively. Without measuring these bases he measures the distance C′ C″, and this multiplied by the number corresponding to the instrument, 20, for instance, will give the distance A B. This is because the angle C′ C C″ is equal to the angle A C B, and the sides C C′ and C C″ are proportional to the sides A C and B C in the triangles C C′ C″ and A B C. Care must be taken to lay off the bases in the same direction from C, that is, both to the right or both to the left of the observer at C as he stands facing the points A and B for the two bases respectively.

Where the instrument is adapted to laying off a right angle also, the observer can place himself on the line between two points, A and B, Fig. 7, and obtain the distance between them in a very simple manner. Being at C, he lays off in the same direction the bases C C′ and C C″, one corresponding to the distance C A and the other to C B, adds the bases, and multiplies their sum by the usual number.

Lieutenant Pratt's instrument consists of four mirrors. Two are set at an angle of 45° and two at a lesser angle. The number of mirrors is the same as in the modified Azémar instrument, which gives three angles. The bases are $\frac{1}{10}$ and $\frac{1}{20}$ of the distance to be determined, and with the longer base the instrument is used like Weldon's.

The method shown in Fig. 6 is applicable to the Weldon range-finder, as well as to those giving a right angle. When the right-angle instruments are used, care must be taken to lay off this angle at the right or at the left extremity of the base in both observations. When A C C′ and B C C″ are both right angles the line C′ C′ will be perpendicular to the line A B, and this affords an easy method of laying off a perpendicular to an inaccessible line, two points of which are visible to the observer. This method can be used also with variable-angle telemeters.

Thanks are due to Capt. W. S. Starring, Ordnance Corps, to Lieut. Sedgwick Pratt, and Lieut. Constantine Chase, Third Artillery, for assistance in the above observations, and to Professor Melville, of Harvard College, for measurement of the angles of the prism.

Fig. 1.

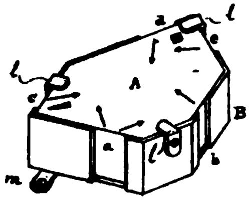



Fig. 2.

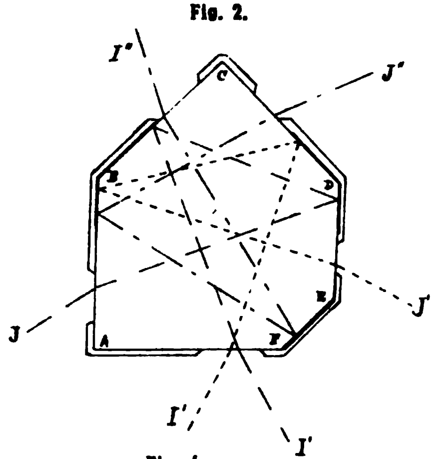



Fig. 5.

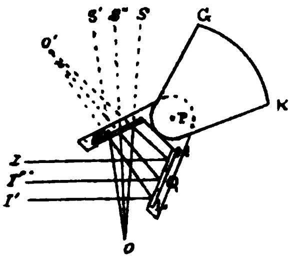



Fig. 4.

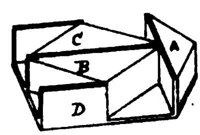



Fig. 3.

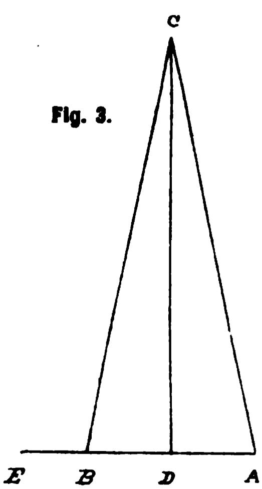



Fig. 6.

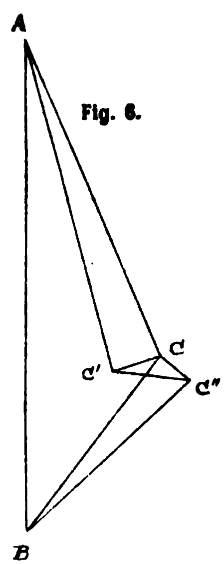
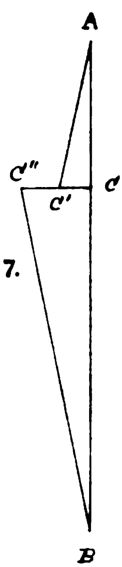



Fig. 7.



# APPENDIX 30.

## PACK OUTFIT FOR HOTCHKISS BREECH-LOADING MOUNTAIN GUN.

(Thirteen plates.)

HEADQUARTERS DEPARTMENT OF DAKOTA,
*Saint Paul, December* 9, 1880.

SIR: Soon after the Hotchkiss breech-loading gun, caliber 1.65, was sent to this department for trial, the question of its proper field transportation was presented, and a board was convened for the purpose of considering the modification of the Mexican pack-saddle, or aparéjo, so generally used on the plains, necessary to meet this especial purpose.

The undersigned, the only remaining members of the original board, respectfully submit the following report upon the subject.

The first gun received was thoroughly tried in the field, and the experience there gained led at once to the adaptation of the aparéjo for its transportation over the peculiar *terrain* in which it is designed to operate.

The conclusions arrived at are so clearly represented in the accompanying drawings that more minute description seems supererogatory.

The Madigan packing boxes, modified by the board to suit the present demands, have been adopted, and their use is shown in plates XI and XIII.

It may here be incidentally mentioned that the board have also considered the value of these boxes in carrying small-arm ammunition, and having reported in favor of their use, the Chief of Ordnance directed the fabrication and issue of forty, which are now undergoing trial in this department.

The board, in the accompanying plates, make provision for packing only the present carriage, the gun, and ammunition, these constituting essentially a "mountain outfit"—meaning thereby *matériel* that can accompany a light column on a trail, leading possibly through "bad lands," alkali plains, difficult passes, or almost fathomless cañons.

Wherever animals can be taken, thither can this little field piece, thus packed, accompany them.

Still the board do not desire, because they make this recommendation in regard to the purpose for which they were convened, to be thereby understood as being in favor of the entire abolition of the so-called "prairie" carriage.

The board are opposed to the shaft-draft as a method of gun traction; the concurrent testimony of all who have attempted to make use of it for any purpose in the Indian country, except, possibly, in the simple guise of the primitive Red River voyageur cart, shows its inutility, nay, its utter impracticability.

The correspondence which has taken place on the subject between the chief ordnance officer at these headquarters and the Chief of Ordnance gives in detail the reasons for this conclusion, which need not be repeated here.

The board are of opinion that an appropriate limber should be furnished for the draft of the gun on long marches. The pack outfit herewith submitted is designed to be used on rapid scouts or demonstrations undertaken without an accompanying train, usually of short duration, and of such route as promises a speedy return to the train, where, as a matter of course, the limber has been left.

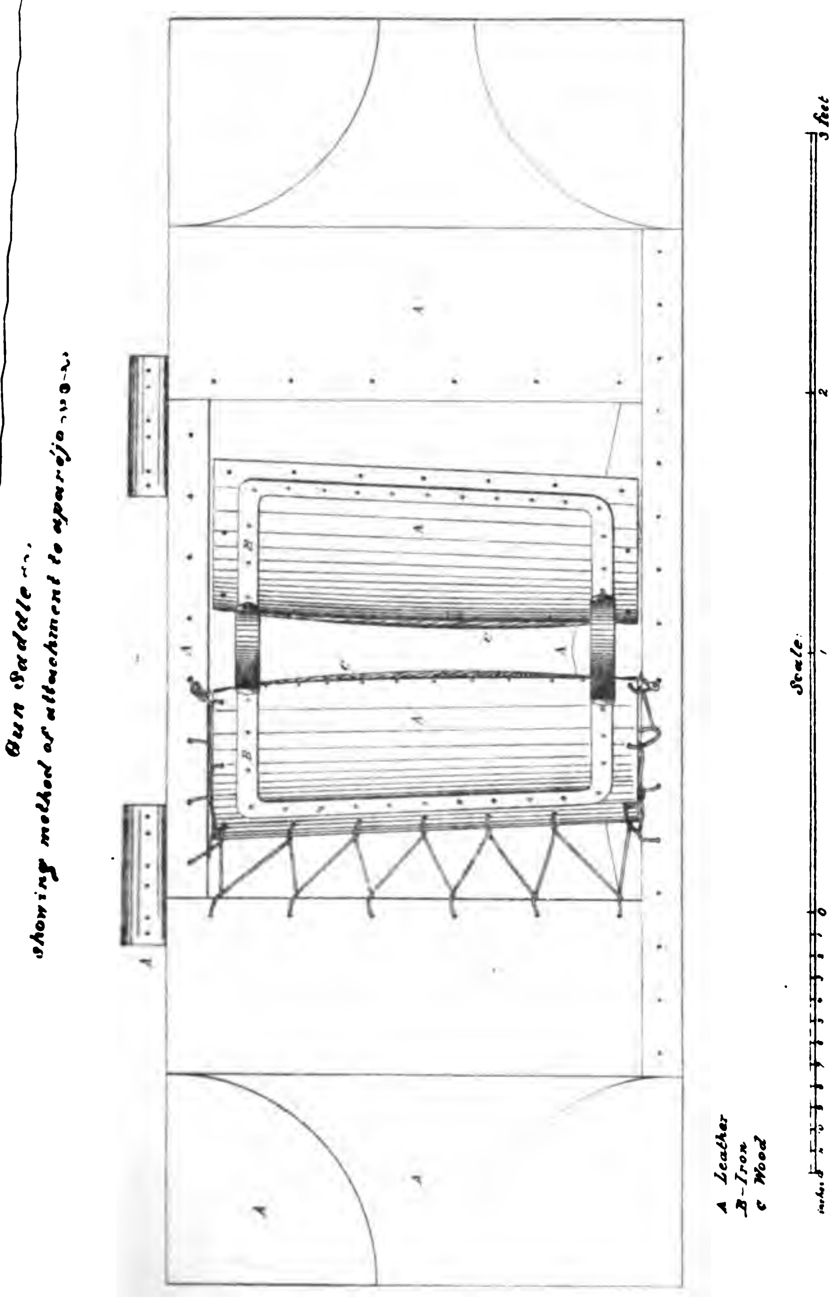
The board believe that the carriage may be materially modified: the axle may be shortened without impairing stability; a more rapidly working system of assembling may be devised; or, indeed, so important a change may be made that the aparéjo-laden mule can himself be used in drawing the gun from point to point on the actual scene of engagement; but the board think that these changes embrace technical questions properly within the province of the Ordnance Department, and to be worked out at its establishments, the board merely indicating desiderata, leaving their practical elaboration to the expert.

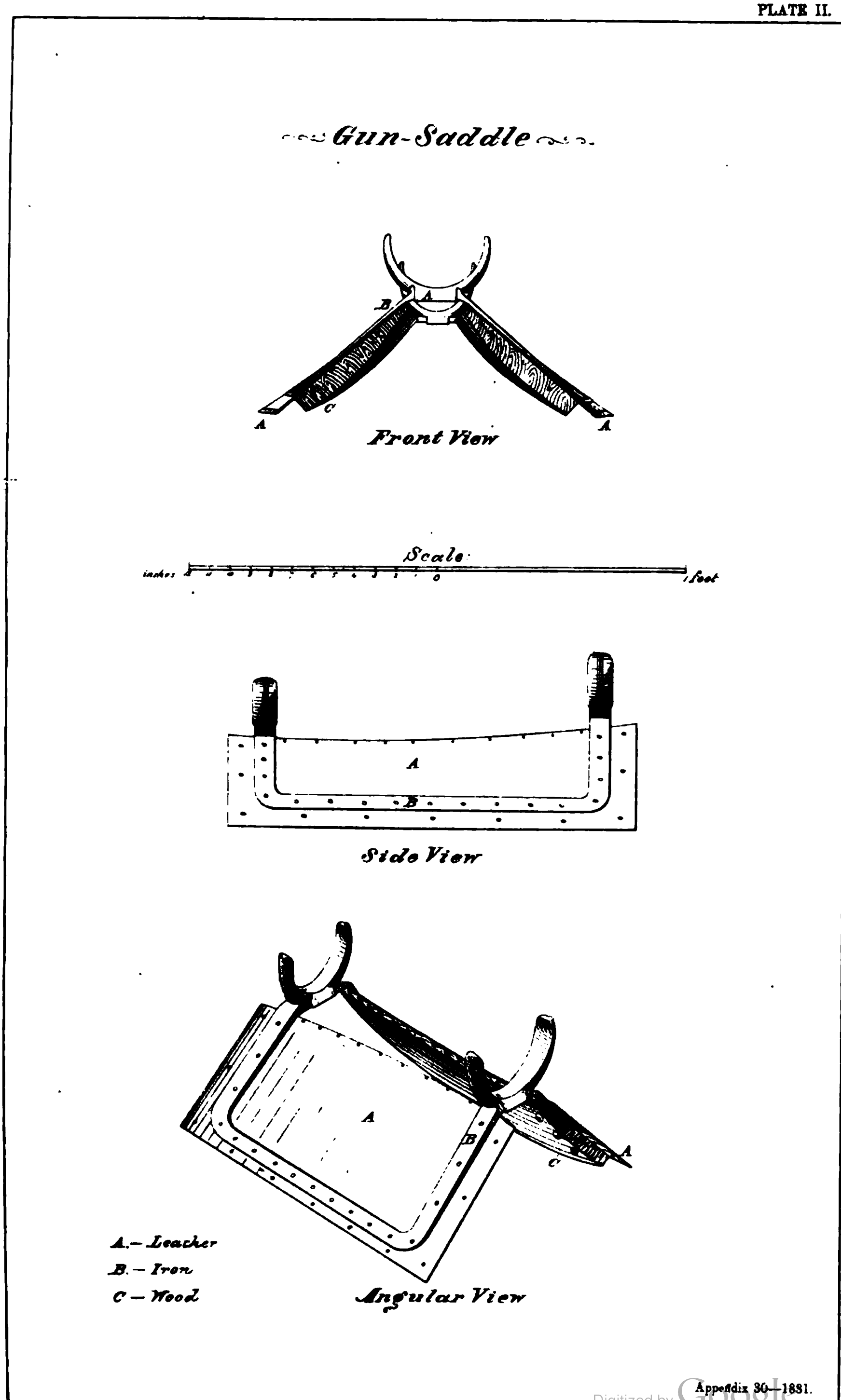
PLATES.

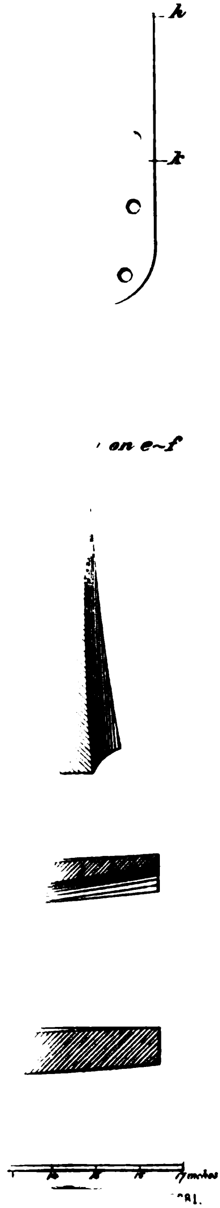
Plate I.—Gun-saddle, recommended by the board and now under trial at Forts Keogh and Custer, with method of attachment to aparéjo.
Plate II.—Various views of the gun-saddle.
Plate III.—Details of wooden tree used in construction of gun-saddle.
Plate IV.—Construction of iron gun-carrier.
Plate V.—Various views of the carriage and wheel-saddle. (Not yet constructed.)
Plate VI.—Side elevation of Madigan ammunition box.
Plate VII.—Top and bottom elevation of Madigan ammunition box. (Smaller size.)
Plate VIII.—End elevation and sectional views of same.
Plate IX.—Horizontal section of larger Madigan ammunition box.
Plate X.—Hub collet, with method of use and lashing.
Plate XI.—Gun packed, with smaller ammunition boxes.
Plate XII.—Carriage and wheels packed.
Plate XIII.—Ammunition boxes packed.

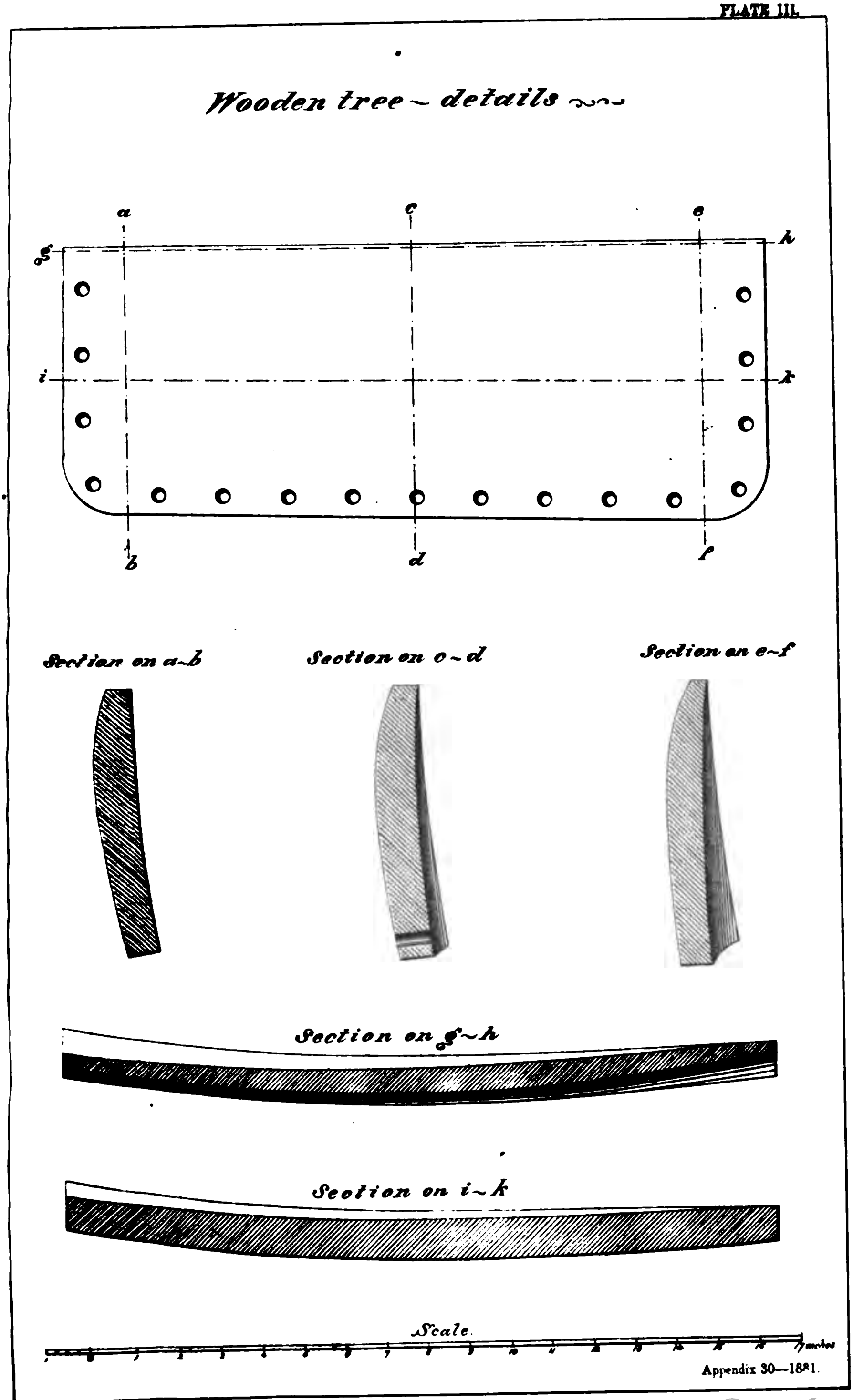
Respectfully submitted.

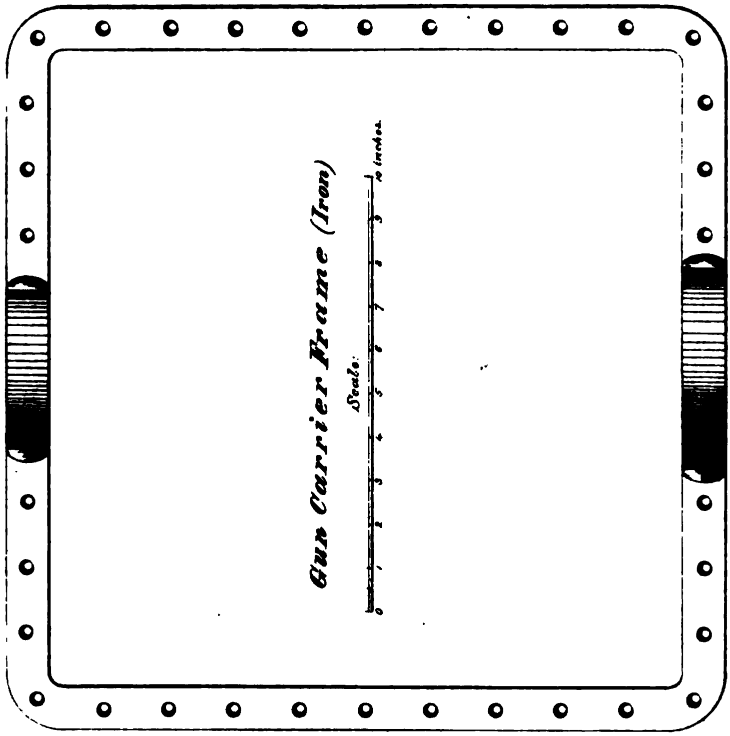
R. P. HUGHES,
*Captain Third Infantry, A. D. C.*
O. E. MICHAELIS,
*Captain of Ordnance, Member and Recorder.*

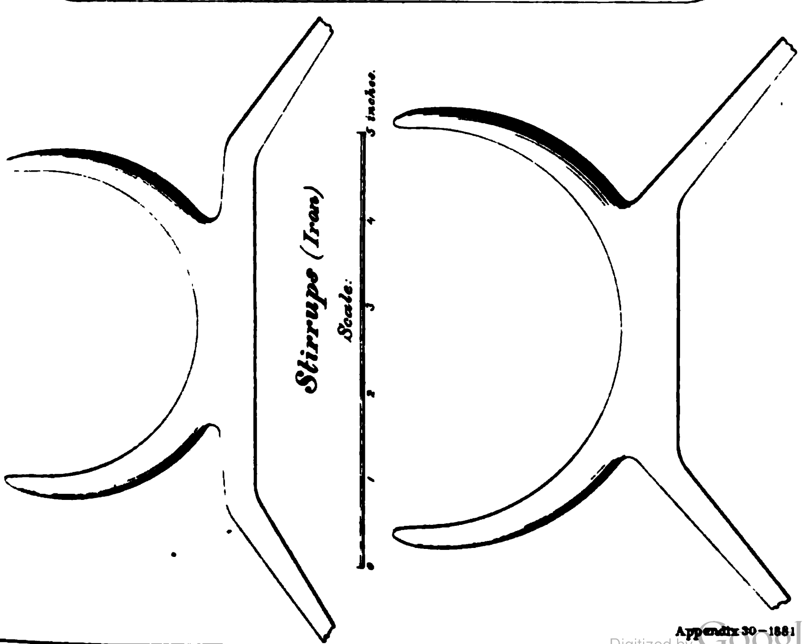

Gun Saddle
showing method of attachment to aparejo
A Leather
B-Iron
C Wood
Scale
inches
3 feet
2
1
0


Gun-Saddle
B
A
C
A
A
Front View
Scale
inches
0
1 foot
A
B
Side View
A
B
C
A
A.– Leather
B.– Iron
C – Wood
Angular View

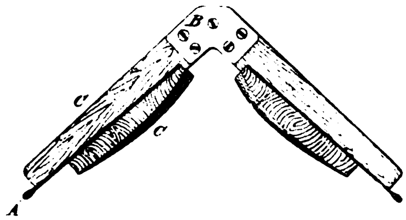

h
k
on e-f
inches


Wooden tree ~ details
a
c
e
g
h
i
k
b
d
f
Section on a~b
Section on c~d
Section on e~f
Section on g~h
Section on i~k
Scale.
inches
Appendix 30—1881.

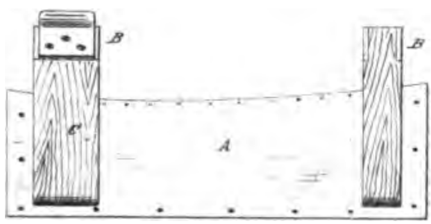

Gun Carrier Frame (Iron)
Scale:
10 inches


Stirrups (Iron)
Scale:
5 inches

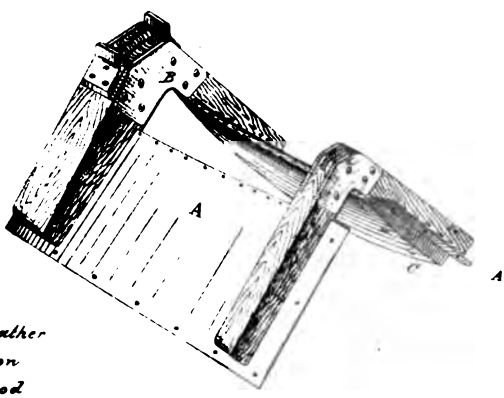
# Carriage and Wheel Saddle.




Front view



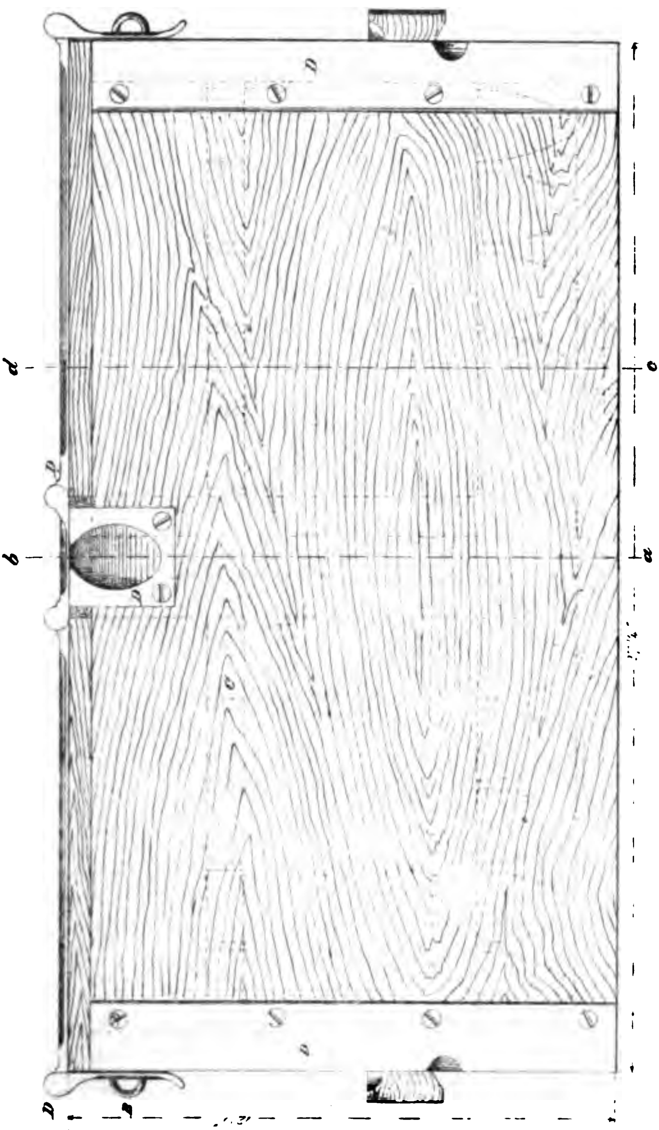

Side view




A – Leather
B – Iron
C – Wood

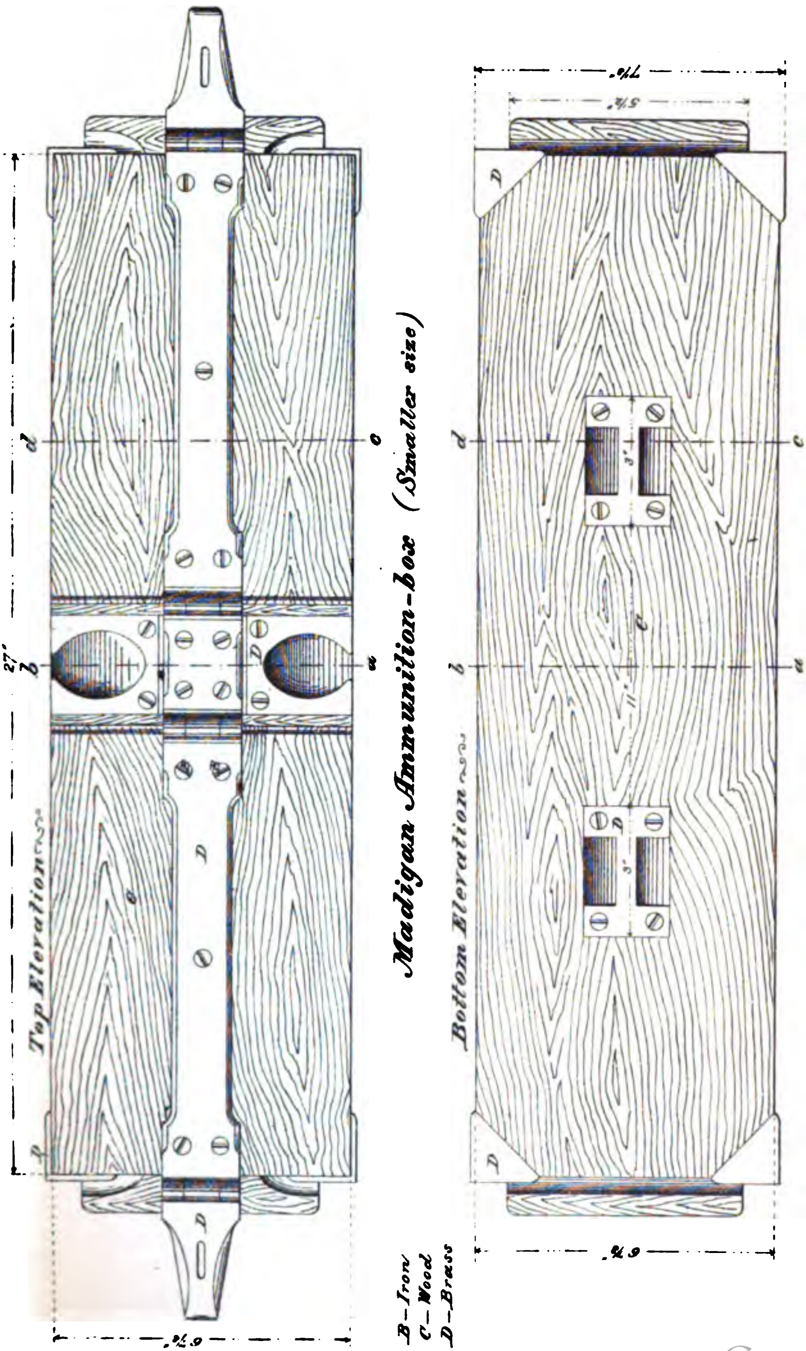
Angular view

## Madigan Ammunition box.



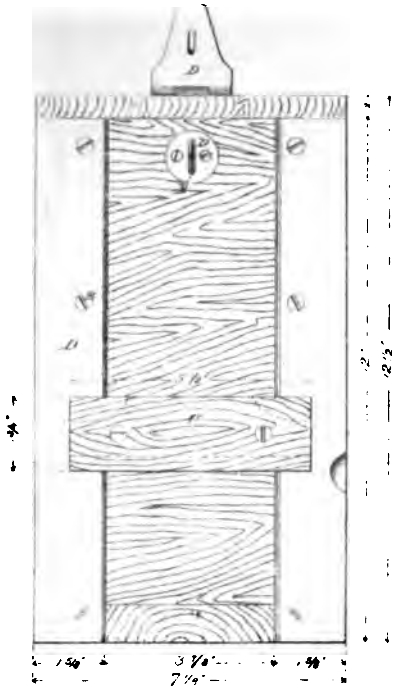
Side Elevation

B — Iron.
C — Wood
D — Brass

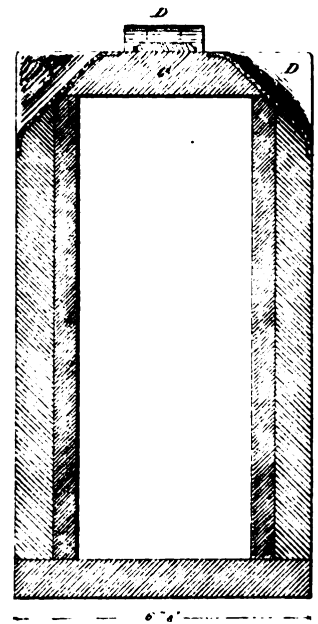



Madigan Ammunition-box (Smaller size)

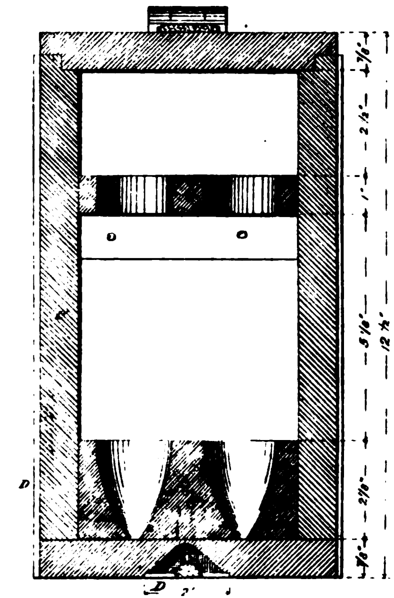
# Madigan Ammunition box (Smaller size)



End Elevation



Sectional view on a-b

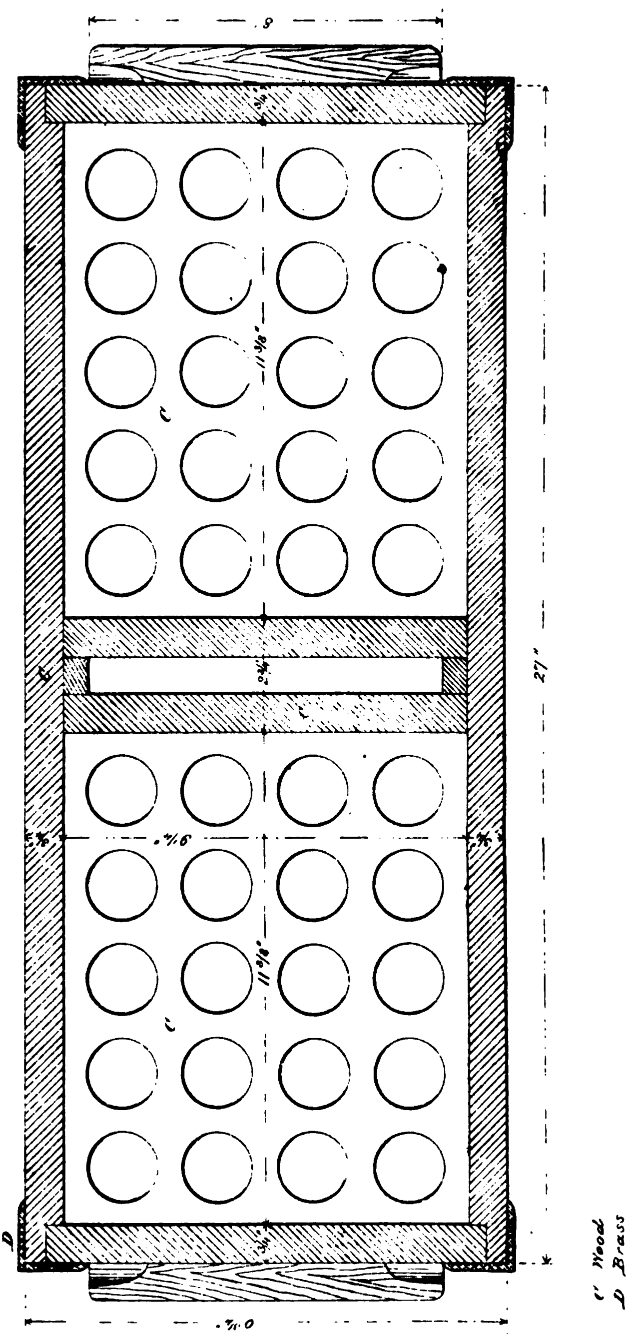


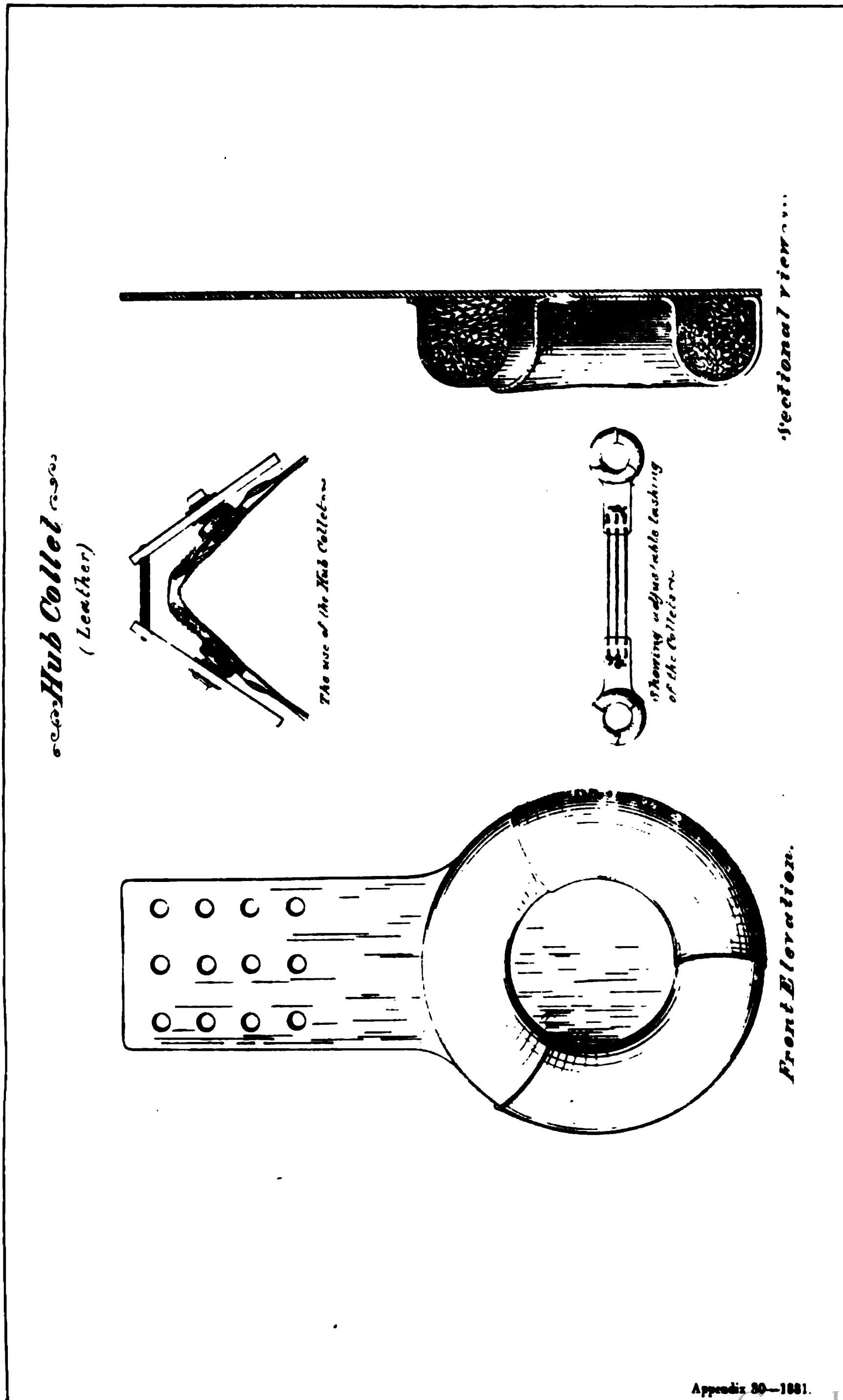
Sectional view on c-d

B - Iron
C - Wood
D - Brass

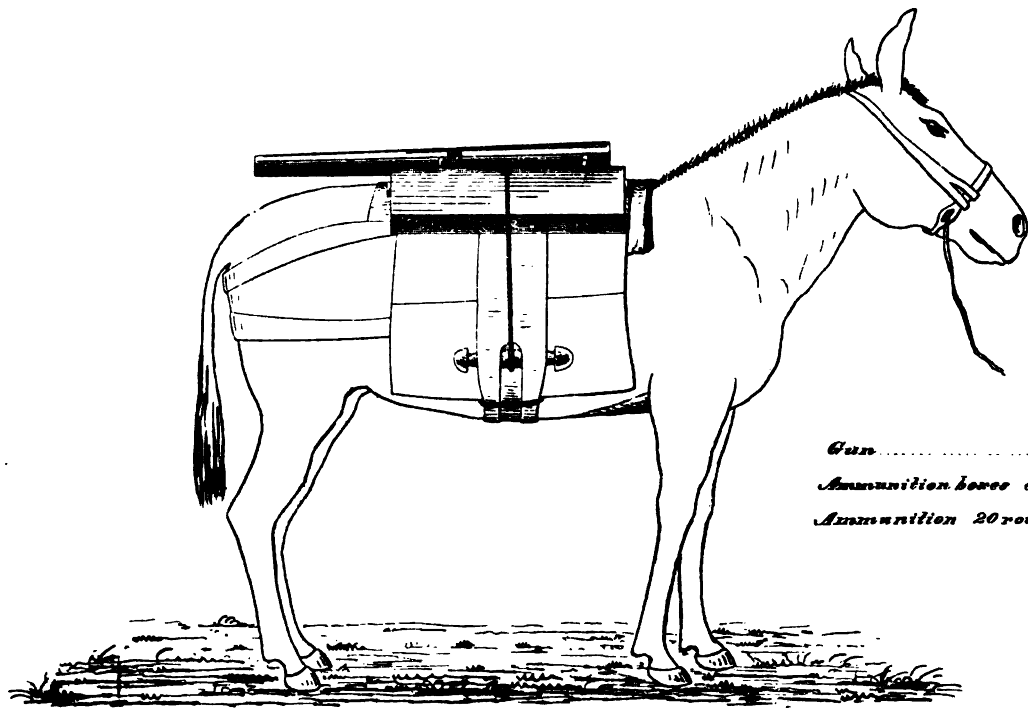
Madigan Ammunition box (Larger size)

Horizontal Section



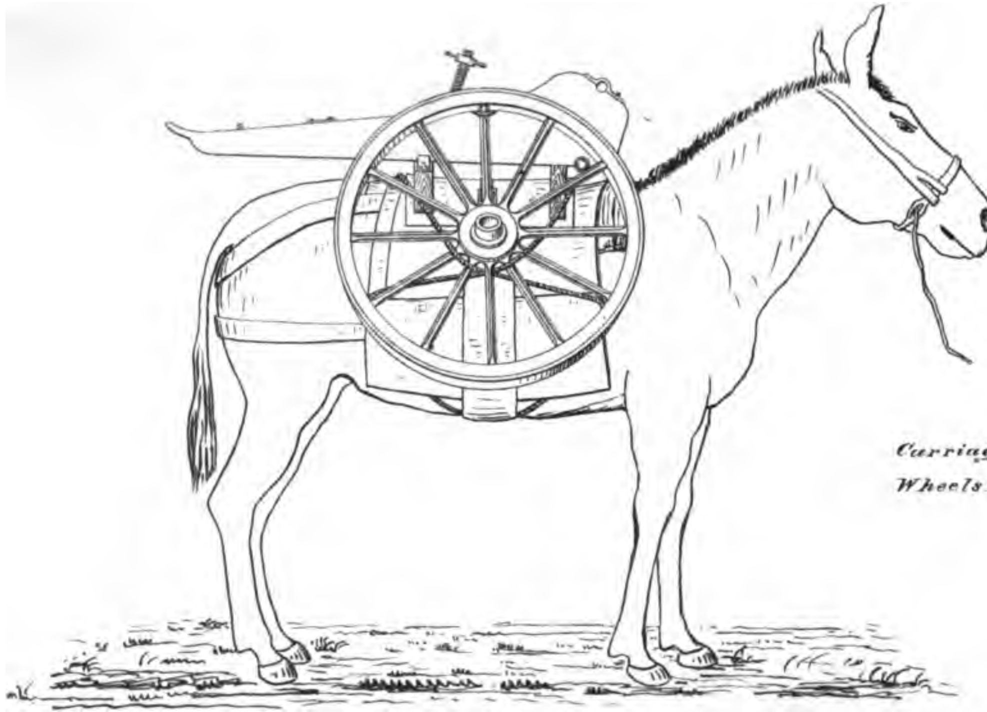

Hub Collet
(Leather)
The use of the Hub Collet
Showing adjustable lashing of the Collet
Sectional view
Front Elevation

Gun packed, with smaller ammunition boxes.

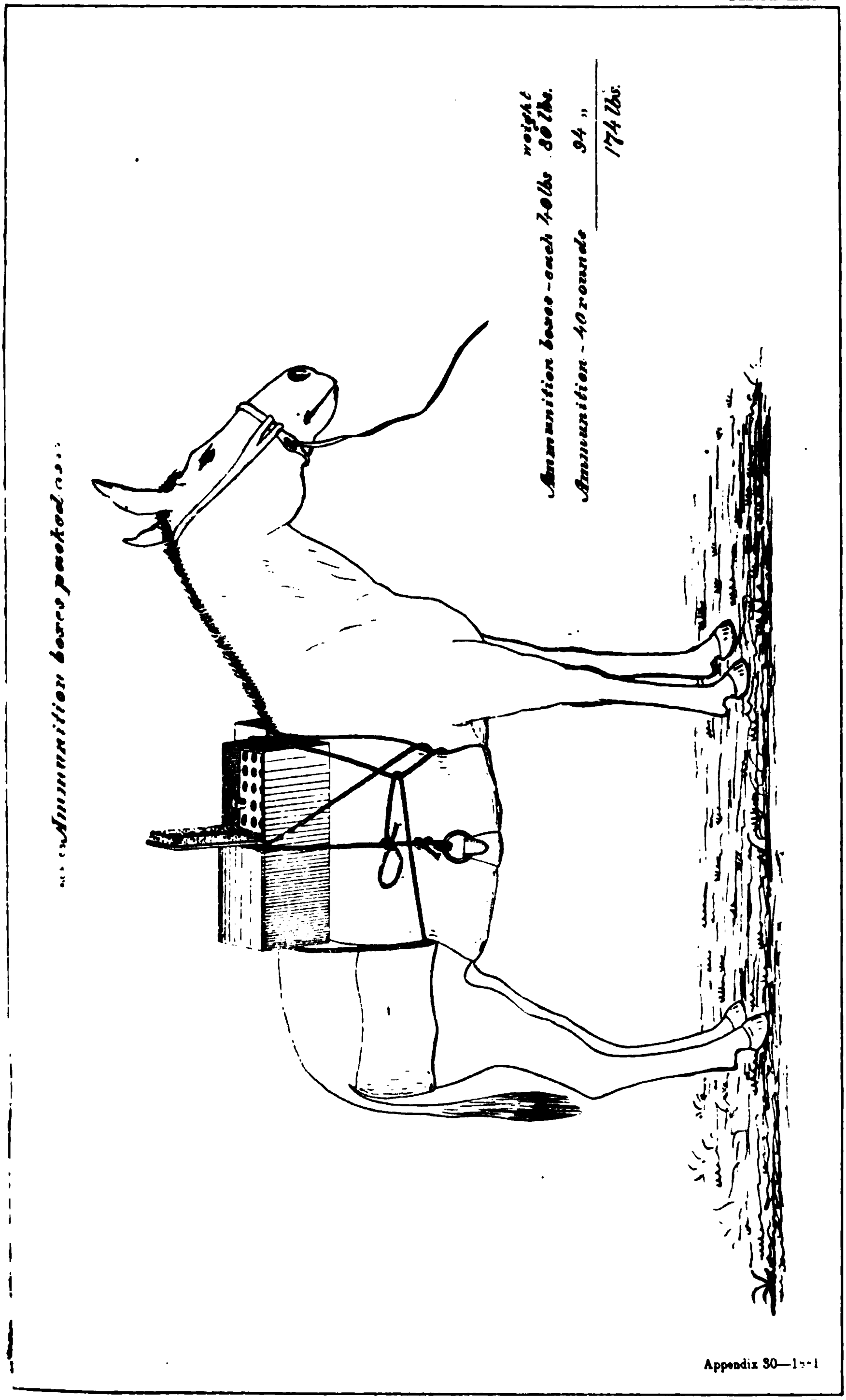


| | weight |
|---|---|
| Gun | 115 lbs. |
| Ammunition boxes each 30 lbs. | 60 " |
| Ammunition 20 rounds | 47 " |
| | 222 lbs. |

*Carriage and wheels packed*



| | weight |
|---|---|
| Carriage ........ | 155 lbs. |
| Wheels ........ | 99 „ |
| | 254 lbs. |


Ammunition boxes packed
Ammunition boxes - each 40lbs weight 80 lbs.
Ammunition - 40 rounds 94 "
174 lbs.

# APPENDIX 31.

RECORD OF TARGET PRACTICE WITH THE HOTCHKISS, GATLING, AND GARDNER MACHINE GUNS, BY CAPT. E. B. WILLISTON, SECOND ARTILLERY.

CORPUS CHRISTI, TEXAS, *January* 1, 1881.

GENERAL: I respectfully submit herewith record of target practice for the year ending December 31, 1880, in compliance with Par. No. 105, Ordnance Regulations, 1877.

Form No. 31 has not been used, as it is not applicable to the armament of this battery.

This report is sent direct, as monthly records of practice have been forwarded regularly to department headquarters.

Owing to circumstances, such as changes of station, long marches, and field service, the target practice has not been as regular as it otherwise would have been.

In the absence of any special instructions regarding practice, I have endeavored to observe field conditions, such as would apply in actual war, so far as possible.

Nothing would be gained by my attempting the trials already made before ordnance officers.

To carry out the plan mentioned, the days for practice have been arbitrarily fixed, regardless of weather.

The guns have been placed at the stake put to indicate the range, whether the ground was favorable or not.

In brief, I have tried to show what may be expected from the guns I have, under conditions of field service, when manned by average gunners. This has been constantly kept in view, trusting that it would meet with your approval.

### FUSES.

The Hotchkiss fuses have proved good, very few failing. Twenty shells have been fired over water during the year for instruction; in each case the shell was exploded. A few fired at the target failed, the fulminate being damaged; and two caused the shell to burst close to the gun.

### PRACTICE GROUND.

The practice ground selected was a plain devoid of brush, nearly level, and soft in places. The target was placed in the highest part of a rise of ground, about 20 feet above the plain, the ground sloping to the front and rear. About fifty yards in front of the target were a number of gravel pits. This location was selected, as it was the exact place that would be taken by an enemy to place a battery with its supports. It was an unfavorable position for guns to attack, but presented conditions not unusual in action. A good range can be obtained near this city up to 6,000 yards and over. With the exception of the rainy months, the whole range is dry and sufficiently hard.

In this connection I may mention that the targets are so arranged

that in case the projectile passes beyond, it goes into the bay, insuring safety and giving an opportunity to observe the effect produced by its striking the water.

WEATHER.

Practice has taken place in good and bad weather, some during wet "northers," amid driving rain and violent gusty winds.

GROUND.

The ground where the gun stood has at times been hard, at others the mud has been half way to the naves of the wheels.

GUNS.

The Hotchkiss revolving cannon have worked to my perfect satisfaction. It is the most accurate and deadly arm of which I have any personal knowledge. The Gatling guns have worked well and given satisfaction. The Gardner gun, recently received, has only been fired a few times; has proved accurate, and has the advantage of simplicity and easy and sure action. It is not as liable to get out of order as the Gatling, and is cleaned with much more ease. The Lowell guns have as yet not been fired, no feed tubes having been sent with them. Reports on the Gardner and Lowell guns will be submitted hereafter.

CARRIAGES.

The Hotchkiss carriages have stood the heat and dryness of this climate perfectly. The only objection observed about the equipment of the carriage is the absence of lock-chains. The recoil-breaks are not strong enough to stand the strain thrown on them by steep pitches, common on the roads in this country. A report on this subject has been already submitted. The other carriages have endured all kinds of exposure without injury, except that the lids of the ammunition chests have warped badly.

AMMUNITION.

The percussion shells used in the Hotchkiss have proved unreliable, owing to the powder in the cartridges having been damaged more or less. Examination has shown that some of the powder was "caked," while in others the powder has been found pulverized to a considerable extent. Target No. 23 shows the results obtained from these unreliable cartridges.

About 2,000 rounds of Frankford ammunition, caliber .45, received by me in unmarked boxes, at Fort Clark, proved to be very much damaged; cause unknown; supposed date of manufacture prior to 1877.

Almost all the ammunition, caliber .45, on hand at the time was wet and damaged by the salt water during the great storm of August last, at which time the park was flooded and the guns for a while under water. The results obtained with this ammunition were unsatisfactory. (See targets Nos. 16, 18, 20, 22, &c.) In all, there were about 5,000 rounds of this damaged ammunition.

Frankford ammunition works better with the Gatling than any other kind that I have tried thus far.

### SIGHTS.

The peep sights have proved a success with all of the guns. Telescopic sights will be used with the Hotchkiss for ranges above 2,000 yards.

### EXPENDITURE OF AMMUNITION.

| | | |
|---|---|---|
| Hotchkiss percussion shell: | | |
| Fired at target | 275 | |
| Fired over water | 20 | |
| | | 295 |
| Frankford, caliber .45: | | |
| Fired at target | 6,000 | |
| Fired over water to show effect of oscillators (all of damaged lot) | 2,311 | |
| | | 8,311 |
| Winchester, caliber .45, fired at target | | 1,760 |

I beg to submit the following recommendations regarding machine guns:

1st. That they be browned.

2d. That peep sights be adopted and the front sights be made finer. That all rear sights be made to work up and down by means of a screw similar to the one on the improved Gardner gun. That rear sights be arranged and graduated for 3,500 yards.

3d. That the oscillatory arrangement now applied to the improved Gardner gun be adopted for the other machine guns, caliber .45. In my opinion it is far superior to the oscillators of the Gatling and Lowell.

4th. That the lids of the ammunition chests be made stronger by means of iron straps—strong enough to prevent warping.

5th. That cartridges with bullets weighing 500 grains be issued to this battery for trial.

# APPENDIX 32.

## A PROPOSED 3.5-INCH BREECH-LOADING RIFLED FIELD-GUN OF WROUGHT-IRON OR STEEL.

BY CAPT. GEORGE W. M'KEE, ORDNANCE DEPARTMENT.

(One plate.)

JUNE, 1881.

GENERAL: I have the honor to forward herewith drawings and specifications for a proposod 3.5-inch breech-loading wrought-iron or steel rifled gun. There is nothing new in this gun; it is but the embodiment of the best features I have been able to collect and assemble from native and foreign sources. The gun is constructed on recognized principles, as the accompanying calculations and references for each and every part will exhibit, and it is believed it embodies—

1st. Great strength, *per se*, as a propulsive engine.

2d. Lightness sufficient for easy transportation and maneuvering.

The calculations and references upon which these views are based are here given in full, so as to assist any inquiry as to their correctness and to enable the inquirers to improve on them if may be. For my object in submitting this gun is to urge upon the authorities the necessity for making an *entirely new field-piece* for the artillery. The time for patching up and converting our very small calibers has passed. A new piece is imperatively demanded, and if this gun does not meet the necessary requirements, I trust that some one else will so modify its dimensions and general features as to render the resulting piece acceptable to the Army.

### THE CHAMBER.

The construction would be simpler and an element of weakness* perhaps obviated, were the lands simply reamed to the depth of the grooves, and thus a long chamber for air-spacing obtained; or, in other words, if the surface of the bore in rear of where the rifling begins were flush with the bottoms of the grooves.

There are considerations, however, which induce me to believe that the chamber should be made as short as possible and the air-space gained in the direction of the radius.

1st. Everything possible in the way of *length* should be given to the rifled portion of the bore.

2d. When a very long cartridge is used, there is "a danger of setting up *wave action* (even when air-space is given) which increases the pressure in the air-chamber abnormally."†

I estimate that the air-chamber for this gun should be 8.837 inches in length, and should have a diameter of 3.98 inches. "In front of the mouth of the chamber and for a length of 1.25 inches the bore is enlarged to the bottom of the grooves, and the lands connected with this point by a bevel 1.0 inch in length."‡

* Rodman's Experiments on Metals for Cannon, and Cannon Powder, p. 152.
† Principles of Gunnery, Rifled Ordnance, by Major Sladen, R. A., p. 37.
‡ Constructor of Ordnance, in Report of Chief of Ordnance, 1880, p. 42.

This will give to the chamber proper a volume of 94.279 cubic inches.

Diameter of chamber $= 3''.98$.
Radius of chamber $= 1''.99$.
Length of chamber $= 7''.587$.

$$\pi\, \gamma^2 \times 7.587 = 12.441 \times 7.587 = 94.279.$$

The entire chamber is $7''.587 + 1''.25 = 8''.837$ in length.

The small frustum of a cone in front of the chamber has a volume of 14.221 cubic inches.

Radius of lower base or end $\gamma = 1''.99$
Radius of upper base or end $\gamma' = 1''.815$
Altitude $= 1''.25$

$$\pi\gamma^2 = 12.441$$
$$\pi\gamma^12 = 10.349$$

$$\sqrt{12.441 \times 10.349} = \sqrt{128.752} = 11.3469$$
$$12.441$$
$$10.349$$

$$*14.221 = 0.4166 \times 34.1369$$

So that if the base of the projectile be even with the beginning of the beveled lands, the entire space in the chamber proper and the frustum will be $= 94.279 + 14.221 = 108.5$ cubic inches.

Now, if we allow 24.5 cubic inches† to a pound of powder, the maximum capacity of this chamber-space would be 4.429 pounds, if it were entirely filled and no cartridge-bag used. So far as the chamber is concerned, it will, therefore, be impossible to get more than 4 pounds into it under ordinary circumstances. And this is deemed a desirable feature,‡ as, for this gun, 3.5 pounds of powder will be a *large*, and 4 pounds a *very large*, charge. It is believed that with from 3.5 to 4 pounds this gun will largely outrange the present 3-inch rifle, and that there can be no incident of field-service warranting, at any time, the use of more than 4 pounds of powder.

Allowing nothing whatever for the cartridge-bag, we would therefore find for the small charge of 3 pounds $108.5 \div 3 = 36.166$ cubic inches of air-space per pound, giving a very small pressure and diminished muzzle velocity.§

For a charge of 3.25 pounds, $108.5 \div 3.25 = 33.38$ cubic inches of air-space per pound, giving a small pressure and a moderate muzzle velocity.

For a large charge of 3.5 pounds, $108.5 \div 3.5 = 31.0$ cubic inches of air-space, giving a moderate pressure and a good muzzle velocity.

And for a very large charge of 4 pounds, $108.5 \div 4 = 27.125$ cubi inches of air-space, giving a high pressure and high muzzle velocity.‖

* I have given the details of all the calculations in order that any one feeling any curiosity there anent may not be subjected to the mechanical work of solving them.

† Principles of Gunnery, Rifled Ordnance, by Major Sladen, R. A., p. 29.

‡ *Idem*, with regard to assigning a certain limit to the maximum pressure in the powder chamber, p. 28.

§ "It is not improbable, under certain conditions, that the amount of air-space may yet be still more increased."—(*Vide* Major Sladen's work, p. 37.)

‖ It is understood, of course, that these are extreme limits between which the air-space per pound will be experimentally determined.

"The most suitable amount of air-space depends upon the system of rifling adopted, the nature of the powder, the weight of charge and projectile, *and must be experimentally determined.* With Woolwich guns and cubical pebble, the most suitable amount of air-space has been found to vary, under present conditions, from 30 to 34 cubic inches per pound of powder."—(*Vide* Sladen, p. 37.)

Capt. C. S. Smith, Ordnance Department, reports that, with the 3.17-inch chambered rifle, using 5 pounds and 13 ounces I. B. sphero-hexagonal powder and a projectile weighing 10 pounds 8 ounces, he obtained 2,026 feet initial velocity and a pressure of 30,000 pounds. The amount of air-space per pound of powder was 32 inches.* Again, with the 3.18-inch breech-loading chambered rifle, using 3 pounds of (I. K.) powder and a projectile weighing 12 pounds, he obtained 1,518 feet initial velocity; pressure not given.† Three pounds of powder in the chamber of the 3.18-inch breech-loading rifle would have an air-space of 35.6 inches per pound. Taking into consideration the steady improvement in these powders, as evinced by the reports, I am convinced that about 3.5 pounds of powder will be a large, efficient, and safe charge for this 3.5-inch gun, and that it may be increased to 4 pounds, if necessary, without straining the gun in the least.

## LENGTH OF RIFLED BORE.

"The object of the artillerist is to get the greatest *amount of work out of a gun with safety*, quite irrespective of the means employed."‡ Therefore, after constructing a gun strong enough in all its parts to resist the strains to which it will be subjected, sufficient length of bore must be given it to utilize all of the powder possible. We wish to find the best *practicable length*, consistent with the efficient working of the gun in actual service, which will meet this requirement. By calculating the number of volumes of expansion of the powder charge contained in the bore of this gun, it is believed that a length of 59.26 inches, rifled bore, will give the maximum work possibly obtainable under the above conditions.

From one of the tables of Noble & Abel, it appears that for 7.9 volumes of expansion, the total work the powder is capable of realizing per pound burnt is 99.23 foot-tons.§

Allowing 24.5 cubic inches to the pound, the space occupied by 3.5 pounds of powder would be $24.5 \times 3.5 = 85.75$ cubic inches.

$$85.75 \times 7.9 = 678.65 \text{ cubic inches.}$$

The volume of the chamber and frustum has already been found = 108.5 cubic inches. Hence the volume of the rifled bore, to give space for 7.9 volumes of expansion, should be $= 678.65 - 108.5 = 570.15$ cubic inches.

Radius of bore $= 1.75$, $\pi r^2 = 9.62115$ square inches, $570.15 \div 9.62115 = 59.26$ inches, or length of rifled bore. The entire length of chamber, frustum, and rifled bore will be $= 7.587 + 1.25 + 59.26 = 68.097$ inches. The maximum work capable of being performed by 3.5 pounds of powder will be $= 3.5 \times 99.23 = 347.305$ foot-tons.

* Report of the Chief of Ordnance, 1879, p. 87.
† Report of the Chief of Ordnance, 1880, p. 53.
‡ Major Sladen's work, p. 36.
§ Major Sladen's work, p. 30. This table, I believe, was calculated from results obtained from experiments with a 10-inch gun.

But with the fair muzzle velocity of 1,500 feet, the calculated energy will be but 249.557 foot-tons at the muzzle—

$$\frac{MV^2}{2 \times 2240} = \frac{WV^2}{2g \times 2240} = \frac{16 \times (1500)^2}{64.4 \times 2240} = 249.557$$

and the "factor of effect" for this velocity will be 72—

$$24955 \div 347 = 72.$$

For the moderate muzzle velocity of 1,350 feet, the muzzle energy will be 202.14 foot tons—

$$\frac{WV^2}{2g \times 2240} = \frac{16 \times (1350)^2}{64.4 \times 2240} = 202.14$$

and the "factor of effect" for this velocity will be 58—

$$202.14 \div 347 = 58.*$$

Following the rule of the English† and "allowing a small percentage for loss of energy, due to the communication of heat, &c., to the gun—which can only be judged by experience—a very close approximation to the muzzle velocity may be obtained. In this case deduct 5 per cent. from the maximum theoretic work, in order to approximate to the work actually realized, which would be 329.65"—

$$347 - 17.35 = 329.65.‡$$

Substituting in this formula

$$\text{muzzle velocity} = \sqrt{2 \times 32.2 = \frac{329.65 \times 2240}{16}} = 1723 \text{ F S}$$

"*which is very nearly the muzzle velocity determined by experiment.*"§

With a projectile weighing 16 pounds and *about* 3.5 pounds of as good a powder as the (I. K.) experimented with by Captain Smith, a velocity in this neighborhood may be relied on. For all practical purposes the muzzle velocity varies *directly* as the square root of the weight of the powder, and *inversely* as the square root of the weight of the projectile, and, when we take into consideration the slight increase in the work of the powder due to the increase in the weight of the projectile, 3.5 pounds of powder and a 16-pound projectile will answer to compare with 3 pounds of powder and a 12 pound shot.‖

## THE FERMETURE.

The breech-block is that devised by the Constructor of Ordnance, a full description of which will be found on page 67, report of the Chief of Ordnance, 1879. The dimensions of the block are shown in the drawings.

* Major Sladen's work, p. 31. † *Idem*, p. 33. ‡ Major Sladen's work, p. 33. § *Idem*. ‖ Report of the Chief of Ordnance, 1880, p. 53.

THE GAS-CHECK.

An ordinary Broadwell ring, or a compound steel and copper check, as described in Appendix H[4], report of Chief of Ordnance, 1879, forms the gas-check. The chamber is enlarged at the rear, to form a recess for it, and its dimensions are shown in the drawings.

THE RIFLING.

If a uniform twist be used, I respectfully suggest, as the best pitch for this caliber, one turn in 11 feet (37.71 calibers), and that there be seven grooves and lands of equal width. If we take a 3.5-inch Butler projectile, its radius of gyration will be found to be 1.175784 inches=0.097982 feet.

This is found from the proportion—

$$700 : 16.5 :: \overline{4.1005358}^3 : x^3$$

or

$$700 : 16.5 :: 68.94661396799 : x^3$$

whence

$$700x^3 = 1137.619130471835$$

$$x^3 = 1.62517018638833$$

$$x = 1.175784.$$

This is a practical calculation for all practical purposes; it gives *somewhat less* than the true radius of gyration, and is therefore on the side of safety, as it throws everything against the projectile. It makes the moment* of the projectile's quantity of motion around its longer axis less than the true moment, and therefore assures us we are within safe limits when estimating the opposing resistances of gravity and the air. It can be shown that with even a greater length of twist than 11 feet a Butler projectile will have sufficient angular velocity to keep its longer axis in the direction of the tangent to the trajectory at a distance of two miles. I am probably biased in favor of this projectile, and also in favor of Captain Butler's ideas of rifling, as from considerable experience with his projectiles I never found *one* to fail, and from the great study he has given the subject I have every confidence in his rifling. Rifling is a matter of judgment, on which there are different opinions, and I have followed Butler in suggesting a twist. If the twist be one turn in 11 feet, and the projectile turn once on its axis in that distance, these velocities below, will explain themselves:

$$\frac{1350}{11} = 122; \ \frac{1400}{11} = 127; \ \frac{1450}{11} = 131; \ \frac{1600}{11} = 145.$$

THE EXTERIOR FORM.

The pressure† will be reduced one-half at $\frac{1}{14}$ of the length of the bore

* Benton's Ordnance Gunnery, pp. 175 and 431.

† See plate, Major Sladen's Work, p. 24. To construct the curves a 10-inch gun was used, with pebble and R. L. G. powders. The pressures of both these powders largely exceed the U. S. (I K), the density of the R. L. G. being 1.68, that of the pebble 1.78, while that of the (I K) is 1.725. As this English 10-inch gun has fewer volumes of expansion than the 3.5-inch gun here proposed, it will be seen that everything is thrown against the latter in calculating proportional distances from the curves. Then the gun is strengthened beyond these distances.

from the starting point of the base of the projectile. This starting point is taken at the beginning of the beveled lands, and, for entire safety, the position of one-half pressure is placed at 19.4 inches from the starting point. It being thus seen that this point of one-half pressure is taken a little less than one-third distance from the starting point, it is obvious that everything has been *thrown against the gun*, and no objection of "wet-nursing," as it is termed by artillerists, can be urged against the resulting dimensions.

The greatest tension, and corresponding pressure of the powder gases, will be reached when the base of the projectile has moved 2.9 inches from the starting point. For perfect safety this, too, is measured from the beginning of the beveled lands.

When the base of the projectile has moved forward this distance of 2.9 inches, we have, therefore, thrown upon the chamber and a small portion of the rifled bore the greatest pressure to which the gun will be subjected. The tangential, the torsion, and longitudinal strains will all act as the projectile has commenced to take the grooves. General Rodman placed the maximum diameter a little forward of the middle of the length of bore subjected to maximum pressure.* He wished to give this part of the gun an excess of strength over other parts, to make a pleasing outline, and to accomplish these objects with the minimum weight of metal. He assumed (R) in determining that value of (L) which gives the maximum bursting tendency from one-fifteenth to one-tenth less than the maximum exterior radius. These same objects may be attained by placing the actual calculated maximum diameter a little forward of the middle point, between the base of the breech and the position 2.9 inches from the starting point of the base of the projectile. Thus there will be no doubt of a sufficiency of metal at that part of the gun where it is most needed.

With a thickness of 4.0 inches over the chamber a pressure of 63,306 pounds per square inch will just reach the low elastic limit of 20,000 pounds. In other words, when this pressure is exceeded the gun will be strained. If the elastic limit be taken at 24,000 pounds, it will require a pressure of 75,967 pounds per square inch to strain the gun.

$$c = 4.0$$

$$M\frac{\delta\nu}{\nu} = 20{,}000, \text{ or } 24{,}000$$

$$P = \text{Pressure}$$

$$P = \frac{\pi}{8} \cdot M\frac{\delta\nu}{\nu} \cdot c\left(\frac{c+2\nu}{\nu^2}\right)^{\dagger} = 63{,}306, \text{or } 75967 \text{ pounds,}$$

according to as $M\frac{\delta\nu}{\nu} = 20{,}000$ or $24{,}000$.

So that, allowing over 5,000 pounds per square inch for the longitudinal and torsion strains, which is greatly in excess of the reality, the gun may be subjected to a pressure of 58,000 pounds per square inch without straining it in the least.

Again, with a gun-iron having the moderate tenacity per square inch of 40,000 pounds, this same equation (substituting 40,000 for $M\frac{\delta\nu}{\nu}$) shows

* Rodman, Experiments on Metals for Cannon, &c., p. 219.
† Prof. W. H. C. Bartlett, Strains on Rifled Guns, &c.

that it will take a pressure of 126,612 pounds per square inch to break this gun. Unless something in the nature of a fulminate is used it cannot readily be done.*

| | Log. |
|---|---|
| $\pi = 3.1416$ | 0.4971509 |
| $M\frac{\delta v}{v} = 20,000$ | 4.3010300 |
| $c = 4$ | 0.6020599 |
| $c + 2v = 7.98$ | 0.9020028 |
| $8 = 8$ | ac 9.0969101 |
| $v^2 = \overline{1.99}^2$ | ac 9.4022938 |
| 63306 | 4.8014475 |

* * * * * * *

| | Log. |
|---|---|
| $\pi = 3.1416$ | 0.4971509 |
| $M\frac{\delta v}{v} = 40,000$ | 4.6020600 |
| $c = 4$ | 0.6020599 |
| $c + 2v = 7.98$ | 0.9020028 |
| $8 = 8$ | ac 9.0969101 |
| $v^2 = \overline{1.99}^2$ | ac 9.4022938 |
| 126612 | 5.1024775 |

The elastic limit being taken at 20,000 pounds, at the distance of 19.4 inches from the starting point of the base of the projectile, the thickness of walls should be 2.57 inches to resist the half of greatest pressure. This is $\frac{63396}{2} = 31,653$ pounds, which, substituted for P in this equation below, after being increased to 40,000 for torsion and longitudinal strains, we will find—†

$$c = -v\left(1 \mp \sqrt{1 + \frac{8}{\pi} \cdot \frac{P}{\frac{M\delta v}{v}}}\right) = 2.57 \text{ inches,}$$

the upper sign being taken. Having allowed here over 8,000 pounds per square inch for torsion and longitudinal strains, it will be seen, perhaps, how unnecessarily strong the gun is, as the walls are in fact 3.21 inches at this point; it being borne in mind that this liberal allowance for strains just reaches the low elastic limit, and does not strain the gun.

The pressure at the muzzle will be one-sixth of the greatest pressure.‡ Taking it at one-fifth we will have $\frac{63306}{5} = 12,661$ pounds per square inch, and allowing the excessive torsion and longitudinal strains of 3,783 pounds per square inch, we will find that the sum of 12,661 and 3,783 = 16,444—substituted for P in this same equation above, will give

$$c = -1''.75\left(1 \mp \sqrt{1 + \frac{8}{\pi}\left\}\frac{16444}{20000}\right.}\right) = 1''.6$$

for the thickness of walls at muzzle.

* Bear in mind $v$ is here the radius of the chamber = 1.99 inches.
† Prof. W. H. C. Bartlett.
‡ Carefully worked out from curves. Sladen, p. 24.

The thickness of metal in rear of breech-block is equal to one and one-half diameters of bore. All the dimensions are given in the drawings, and an attempt has been made to show the curve of the breech, but, as I am a poor draughtsman, this has not been very successful. An expert draughtsman could readily put in very graceful Rodman curves for the breech and the chase in front of the trunnions, materially adding to the beauty of the piece.

These calculations are made for wrought-iron with the low elastic limit of 20,000 pounds. The exterior curves of the gun are so simple that the alteration of a few dimensions will cause the curves to conform to steel, or bronze, or steel bronze.

### CENTER OF GRAVITY.

In order to find the center of gravity of the gun a very fine piece of well-seasoned poplar was planed out to a thickness of one-fourth of an inch. This was tested for homogeneity by suspending it from different points, and the center of gravity found to coincide with the center of figure almost identically. The distorted half-section of the gun was then traced on the board so as to represent its entire length, but only one-half was taken of the squares of the semi-diameters. This, it was thought, would give a half section of such proportions as to render the probability of error a minimum. The method is given in the Report of the Chief of Ordnance, 1880, p. 185. By it the distance of the center of gravity from the base of the breech, measured on the axis, was found to be 31.17 inches. By calculation this distance was found to be 31.5488 inches, making a difference of 0.3788 inches between the two approximations. The calculation was made according to the general principle as laid down in Report of Chief of Ordnance, 1880, p. 184.

The details of this calculation accompany this paper. As the process is a familiar one it is respectfully suggested that they be simply filed.

The plane of reference is taken perpendicular to the axis at the base of the breech:

*First frustum.*

A conical frustum from face of muzzle to front of breech-block.

$R =$ radius of large end; $\nu =$ radius of small end.

$R = 4 + 1.99 = 5.99$; $\nu = 1.75 + 1.6 = 3.35$.

Area face of muzzle $= \pi \nu^2 = 3.1416 \times \overline{3.35}^2 = 35.2566$.

Area section front of breech-block $= \pi R^2 = 3.1416 \times \overline{5.99}^2 = 112.7209$.

| | |
|---|---|
| $\sqrt{35.2566 \times 112.7209} =$ | 63.0409 |
| | 112.7209 |
| A = altitude = 68.097 | 35.2566 |
| | 211.0184 |
| $\frac{68.097}{3} =$ | 22.699 |
| Volume of entire frustum = | 4789.9066 cubic inches. |
| Volume of bore and chamber = | 678.65 |
| Volume of solid part = | 4111.2566 |

$$(R + \nu)^2 = \overline{5.99 + 3.35}^2 = \overline{9.34}^2 = 87.2356$$

$$R^2 = \overline{5.99}^2 = \quad 35.8801$$
$$R\nu = 5.99 \times 3.35 = \quad 20.0665$$

$$\frac{(R + \nu)^2 + 2R^2}{(R + \nu)^2 - R\nu} = \frac{87.2356 + 71.7602}{87.2356 - 20.0665} = 2.3670$$

$\frac{A}{4} = \frac{68.097}{4} = 17.02425$; $2.3670 \times 17.02425 = 40.29639975$, which is the distance of the center of gravity of this frustum from the face of the muzzle.

The entire length of the piece $= 59.26 + 8.837 + 4.1 + 5.28 = 77.477$ inches. Hence $77.477 - 40.29639975 = 37.18060025 = x_1 =$ distance of center of gravity of this frustum from plane of reference.

*Second frustum.*

A conical frustum included between sections perpendicular to the axis at front and rear of breech-block.

$R =$ radius of large end; $\nu =$ radius of small end;
$R = 4 + 1.99 = 5.99$; $\nu = 3.76 + 1.99 = 5.75$

Area large end $= \pi R^2 = 3.1416 \times \overline{5.99}^2 = 112.7209$

Area small end $= \pi\nu^2 = 3.1416 \times \overline{5.75}^2 = 103.86915$

$$\sqrt{112.7209 \times 103.86915} = 108.204$$

| | |
|---|---|
| | 108.204 |
| | 112.7209 |
| $A = 4.1$; $\frac{4.1}{3} = 1.366$ | 103.86915 |
| | 324.79405 |
| | 1.366 |
| Volume of entire frustum $=$ | 443.6686723 |

This is solid, as it includes the breech-block.

$$(R + \nu)^2 = \overline{5.99 + 5.75}^2 = \overline{11.74}^2 = 137.8276$$
$$R^2 = \overline{5.99}^2 = \quad 35.8801$$
$$R\nu = 5.99 \times 5.75 = \quad 34.4425$$

$$\frac{(R + \nu)^2 + 2R^2}{(R + \nu)^2 - Rr} = \frac{137.8276 + 71.7602}{137.8276 - 34.4425} = 2\ 0272$$

$\frac{4.1}{4} = 1.025$; $2.0272 \times 1.025 = 2.07788 =$ distance of center of gravity of this frustum from its smaller end. The small end is *toward* the base of the breech, hence $x_1 = 2.07788 + 5.28 = 7.35788 =$ distance of center of gravity of this frustum from plane of reference.

*Third frustum.*

A conical frustum included between rear of breech-block and a section perpendicular to axis, whose radius is equal to 5.50 inches.

$R = 5.75 =$ radius of large end; $\nu = 5.50 =$ radius of small end.
$R = 3.76 + 1.99 = 5.75$; $\nu = 3.51 + 1.99 = 5.50$.

$$\text{Area large end} = \pi R^2 = 3.1416 \times \overline{5.75}^2 = 103.86915$$

$$\text{Area small end} = \pi \nu^2 = 3.1416 \times \overline{5.50}^2 = 95.0334$$

$$\sqrt{103.86915 \times 95.0334} = 99.353$$

$$A = 3.969; \quad \frac{3.969}{3} = 1.323$$

| | |
|---|---|
| | 99.353 |
| | 103.86915 |
| | 95.0334 |
| | 298.25555 |
| | 1.323 |
| Volume of entire frustum | = 394.59209265 |
| Volume of breech-opening | = 49.39077 |
| Volume of solid part | = 345.20132265 |

$$(R + \nu)^2 = \overline{5.75 + 5.50}^2 = \overline{11.25}^2 = 126.5625$$

$$R^2 = \overline{5.75}^2 = 33.0625$$

$$R\nu = 5.75 \times 5.50 = 31.625$$

$$\frac{(R+\nu)^2 + 2R^2}{(R+\nu)^2 - R\nu} = \frac{126.5625 + 66.1250}{126.5625 - 31.625} = 2.0296$$

$\frac{3.969}{4} = 0.99225$; $2.0296 \times 0.99225 = 2.0138706 =$ distance of center of gravity of this frustum from its smaller end. The small end is *towards* the base of the breech, hence $x = 2.0138706 + 1.311 = 3.3248706 =$ distance of center of gravity of this frustum from the plane of reference.

*Fourth frustum.*

A conical frustum included between base of breech and a section perpendicular to axis, whose radius is equal to 5.50.

$R =$ radius of large end; $\nu =$ radius of small end.
$R = 3.51 + 1.99 = 5.50$; $\nu = 2.49 + 1.99 = 4.48$.

$$\text{Area, large end} = \pi R^2 = 3.1416 \times \overline{5.50}^2 = 95.0334$$

$$\text{Area, small end} = \pi \nu^2 = 3.1416 \times \overline{4.48}^2 = 63.335$$

* * * * * * *

$$\sqrt{95.0334 \times 63.335} = 77.5818$$

$$95.0334$$

$$A = 1.311;\quad \frac{1.311}{3} = 0.437 \qquad 63.335$$

$$235.9502$$

$$0.437$$

| | |
|---|---|
| Volume of entire frustum | = 103.1102374 |
| Volume of breech opening | = 16.3102167 |
| Volume of solid part | = 86.8000207 |

$$(R + \nu)^2 = \overline{5.50 + 4.48}^2 = \overline{9.98}^2 = 99.6004$$

$$R^2 = \overline{5.50}^2 = 30.25$$

$$R\nu = 5.50 \times 4.48 = 24.64$$

$$\frac{(R+\nu)^2 + 2R^2}{(R+\nu)^2 - R\nu} = \frac{99.6004 + 60.50}{99.6004 - 24.64} = 2.1357$$

$\frac{1.311}{4} = 0.32775$; $2.1357 \times 0.32775 = x_1 = 0.699975675$ = distance of center of gravity of this frustum from the plane of reference.

*Moments.*

| | | | | | |
|---|---|---|---|---|---|
| First frustum, | 4111.2566 | × | 37.18060025 | = | 152858.95 |
| Second frustum, | 443.6686723 | × | 7.35788 | = | 3264.4609 |
| Third frustum, | 345.20132265 | × | 3.3248706 | = | 1147.749 |
| Fourth frustum, | 86.80000207 | × | 0.699975675 | = | 60.7578 |
| | 4986.92659702 | | | | 157331.9177 |

Center of gravity of gun from plane of reference =

$$X = \frac{157331.9177}{4986.92659702} = 31.5488 \text{ inches.}$$

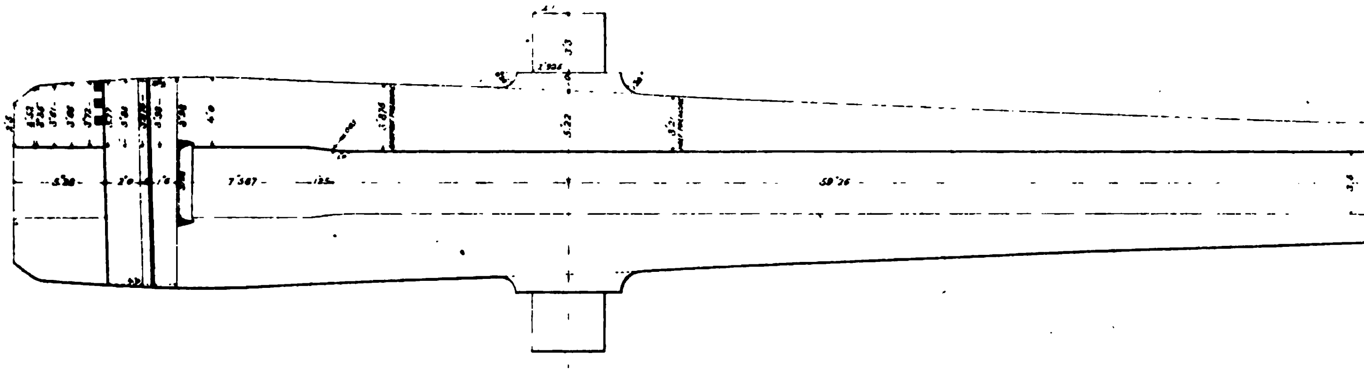
To insure a slight preponderance, as a counter to drooping of muzzle, the axis of trunnions in the drawings is taken at 31.76 inches from the base of breech.

From the volume of the gun as given above we see that with iron of density of 7.781, allowing 55 pounds for the trunnions and rim base, this gun will weigh 1,451 pounds.* With an iron of the density 7.675 (coiled wrought-iron for gun-tubes) it will weigh 1,431 pounds. As, in putting in the Rodman curves in front of the trunnions, some metal may be removed advantageously, the weight of the gun is given at 1,400 pounds. When it is considered how easily the 12-pounder Napoleon is handled with its weight of 1,250 pounds, and we take into consideration the rack of the carriage and the recoil, this weight (1,400 pounds) is deemed about right.

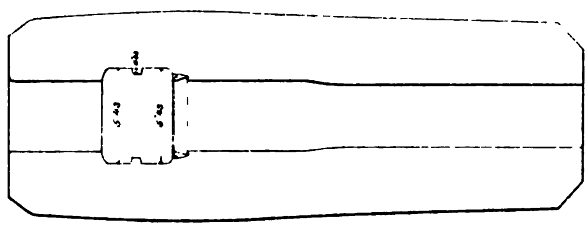
In applying these references to this gun, I am greatly indebted to Col. D. W. Flagler, Capt. C. S. Smith, and Lieut. L. L. Bruff, Ordnance Department, for much information and assistance.

| | |
|---|---|
| * Report of Chief of Ordnance, 1880, p. 88 .......... | 7,704 |
| * Jones & Laughlin's Book, p. 240 .......... | 7,858 |
| | 2) 15,562 |
| | 7,781 |

HORIZONTAL SECTION THROUGH AXIS OF 3½-INCH B. L. WROUGHT IRON RIFLE.




VERTICAL SECTION THROUGH BREECH OF 3½-INCH B. L. WROUGHT IRON RIFLE.



Scale:

0 5 10 15 20 Inches

## APPENDIX 33.

### REPORT ON THE COMPARATIVE MERITS OF SHELLS WITH RUBBER SUPPORTING ANVILS AND THE SERVICE CARTRIDGE SHELL FOR USE BY TROOPS IN AIMING DRILLS.

BY LIEUT. C. C. MORRISON, UNDER THE DIRECTION OF THE COMMANDING OFFICER OF THE NATIONAL ARMORY.

(One plate.)

OCTOBER 3, 1881.

SIR: In accordance with your instructions I have tested the shells with rubber-supporting anvils, devised by one of the employés at Watertown arsenal, for protecting the firing-pin from breaking in the snapping necessary in aiming drill. The device consists of a brass solid-head shell for outside primed cartridges, the bottom of the primer cup of which is drilled out. A plug of rubber is forced into the shell, filling the same for a distance of six-tenths of an inch, projecting into and filling the cup.

Two forms were submitted, one in which the cup was filled flush with the face of the head, the other having the rubber project .05 of an inch beyond the face of the head.

To determine the efficiency of the device eleven firing-pins were taken from the same tray of current manufacture, to be experimented with.

I had but four of the shells with the rubber anvil, just filling the cup, and one with it projecting beyond the face.

On these first four the hammer was snapped till, in succession, one pin was broken on each.

The average number of blows necessary to break the pin was 1,300.

The hammer was snapped on the one shell, with the anvil projecting, till two pins had been broken, one sustaining 2,840 blows, the other 4,780, giving a mean of 3,810 blows.

The rubber anvil had by this time had a hole about .05″ deep pricked in it.

I then snapped till broken, on service Frankford folded head shells, the remaining five pins; these shells were changed after each twenty blows, and the five pins resisted, before breaking, on an average 1,332 blows.

It appears from these experiments that the shell, with the rubber filling flush with the face of the head, presents no advantage over the service shell, other than that it does not need to be replaced frequently by a new one, as the rubber anvil sustained but little injury.

The shell, however, with the rubber cushion projecting beyond the face, so supports the pin as to prevent the point jumping off, and therefore does lengthen materially the life of the pin.

Each of the eleven pins broke just beyond where it is supported in its lowest position.

It is necessary to leave them thus unsupported to prevent wedging in the block.

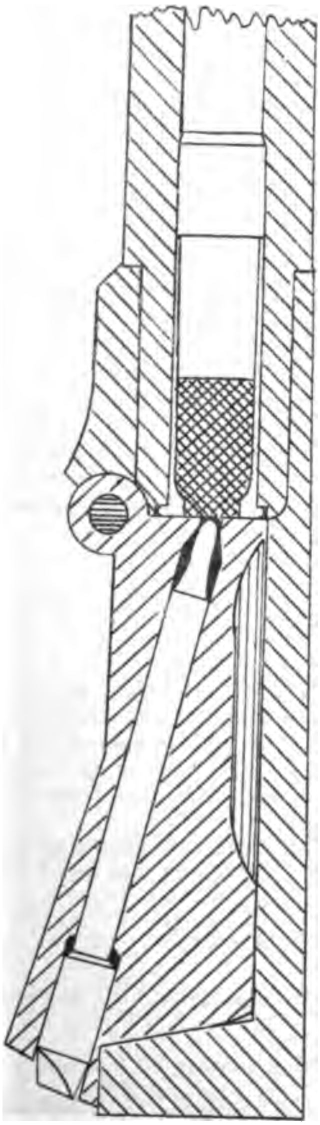
The inertia of the end of the pin beyond this point causes the molecules to rearrange themselves gradually till a section of weakness is developed, such that the point is finally jumped off.

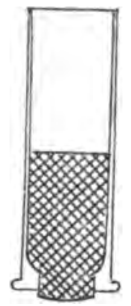
Throughout the experiments the same rifle was used. It was held in a vertical position that the pin might receive the full force of the blow. Should the department decide to use such shells for aiming drill, it would facilitate their entrance into the chamber, if dummy cartridges were used.

The same end could be attained by heavily crimping, or even bottling the shell. This latter might seem necessary to prevent the rubber being driven forward in the shell.

Experiment, however, demonstrates that the friction and wedging of the rubber under the blow is sufficient to prevent it moving; indeed, it is almost impossible to drive it out with a drift.

Sectional drawings are submitted, showing the firing-pin in the block; second, the rubber-filled shell; third, the firing pin as broken.





# APPENDIX 34.

## REPORT ON THE TRAJECTORY OF A PROJECTILE IN VACUO.

BY CAPT. JOHN E. GREER, UNDER THE DIRECTION OF COL. JAMES G. BENTON, ORDNANCE DEPARTMENT.

NATIONAL ARMORY, *July* 20, 1881.

SIR: In relation to the question which arose in a recent conversation with yourself as to whether the trajectory of a projectile in vacuo was really a parabola, as generally accepted, I have the honor to submit the following remarks:

The instant the projectile leaves the muzzle of the piece it becomes subject to the same laws that govern the motion of the bodies of the solar system. In fact, it may be regarded as a body describing an orbit around the earth as the center of attraction.

On page 201, Bartlett's Analytical Mechanics, may be found the following general polar equation of the orbit of a single body $M_1$, the primary, revolving about a central body M:

$$r = \frac{\frac{4c^2}{Km}}{1 + \sqrt{1 + \frac{4c^2}{K^2m^2}\left(V_1^2 - \frac{2Km}{r_1}\right)} \cos(a + \varphi)}, \qquad (1)$$

in which $r$ is the radius vector; $c$ the area passed over by $r$ in a unit of time; K the reciprocal attraction of a unit of mass at the unit's distance; $m$ the sum of the masses $M_1$ and M; $r_1$ the initial value of $r$; $V_1$ the velocity corresponding to $r_1$, and $(a + \varphi)$ the angle made by the radius vector with the fixed line. On the same page will also be found the following:

"Comparing this with the general polar equation of a conic section referred to the focus as a pole, viz:

$$r = \frac{a(1 - e^2)}{1 + e\cos(a + \varphi)}, \qquad (2)$$

we find $a(1 - e^2) = \frac{4c^2}{Km}$, (3); and $e^2 = 1 + \frac{4c^2}{K^2m^2}\left(V^2 - \frac{2Km}{r_1}\right)$, (4);

and this last value will be greater or less than unity according as $V_1^2$ is greater or less than $\frac{2Km}{r_1}$." But $e$ is eccentricity of the curve, and

$\left.\begin{array}{l} e < 1 \\ e = 1 \\ e > 1 \end{array}\right\}$ are the conditions indicative of an ellipse, parabola, or hyperbola.

The orbit is therefore an ellipse, parabola, or hyperbola, according as $V_1^2 <, =, \text{or} > \frac{2Km}{r_1}$, or, as expressed by Professor Bartlett, after sub-

stituting for $m$ its value, multiplying both members by $M_1$ and multiplying and dividing the second member by $r_1$,

$$\text{“}M_1 V_1^2 < \frac{2K(M + M_1) M_1 r_1}{r_1^2};$$

$$M_1 V_1^2 = \frac{2K(M + M_1) M_1 r_1}{r_1^2};$$

$$M_1 V_1^2 > \frac{2K(M + M_1) M_1 r_1}{r_1^2};$$

that is, according as the living force of the primary at any point of its orbit is less than, equal to, or greater than twice the work its relative weight, at that point, would perform over a distance equal to its radius vector. So that a primary may describe *any of the conic sections* as well as the ellipse, the only condition for this purpose being an *adequate value for its velocity.*”

Now, since the attracting force varies inversely as the square of the distance, the acceleration on the projectile, or $F_1$, equals $\frac{Km}{r^2}$, and for a point of the orbit at which $r_1$ is the radius vector, $F = \frac{Km}{r_1^2}$.

Now, suppose a point on the earth's surface—that of the firer—as that at which the value of $r$ is $r_1$; that is the radius of the earth at that point. $V_1$ will then be the initial velocity of the projectile, and $F$ becomes for this *particular point* $g$, the force of gravity, $Km = F r_1^2 = g r_1^2$ and $\frac{2Km}{r^1} = 2 g r_1$.

The conditions above expressed then become $V_1^2 <, =,$ or $> 2 g r_1$.

Suppose for convenience the radius of the earth to be 4,000 miles, as it is nearly, when $V_1^2 <, =$ or $> 64.32 \times 4000 \times 5280^1$.

If $V_1$ therefore be less, equal to, or greater than 36,857 feet per second, the trajectory will be an ellipse, parabola, or hyperbola. As such a velocity is absolutely inconceivable for a projectile fired from a gun, it follows that *in all cases the trajectory is an ellipse.* This discussion, it will be remembered, is based on the supposition that there are but two bodies, the projectile and the earth. As the earth itself moves around the sun the trajectory is corresponding]y modified. This consideration, however, applies with equal force to the method by which it has always been demonstrated to be a parabola. In addition, the latter method has necessitated regarding right lines drawn from different points of the trajectory to the earth's center as parallel, when in reality they are not so, and this lack of parallelism is considerable if the range be one of several miles.

Should it be desired to find the particular ellipse, replace $e$ in equations (3) and (4) by its value $\sqrt{\frac{a^2 - b^2}{a^2}}$, in which $a$ and $b$ are the semi-transverse and conjugate axes, respectively, and there will result $\frac{4c^2}{Km} = \frac{b^2}{a}$ and $\frac{a^2 - b^2}{a^2} = 1 + \frac{4c^2}{K^2 m^2}\left(V_1^2 - \frac{2Km}{r_1}\right)$.

Substituting $g r_1^2$ for $K m$, equating values of $4c^2$ and solving with respect to $a$, we have,

$$a = \frac{g r_1^2}{2 g r_1 - V_1^2}; \tag{5}$$

that is, the value of $a$ is given in known terms.

To find the semi-conjugate axis, we have, Bartlett, page 202, $b = V_1 r_1 \sqrt{\frac{a}{K\,m}} \sin \epsilon$, in which $\epsilon$ denotes the angle made by the orbit or its tangent at the point to which $r_1$ is drawn, with $r_1$.

Substituting for K $m$ its value $gr_1^2$, we have $b = V_1 \sqrt{\frac{a}{g}} \sin \epsilon$.

If the axis of the piece be horizontal, $\epsilon$ will be 90°, Fig. 1; but if the piece be fired under angle I, $\epsilon$ will be 90° ± I, Fig. 2, sin $\epsilon$ = cos I.

*Fig. 1.*

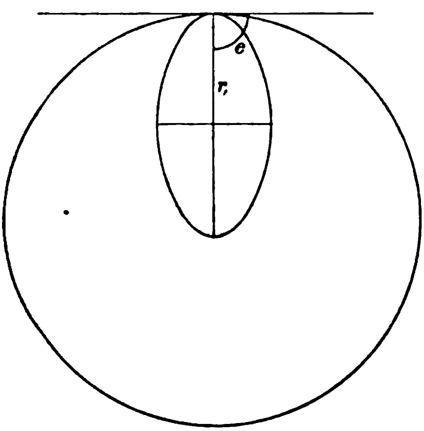
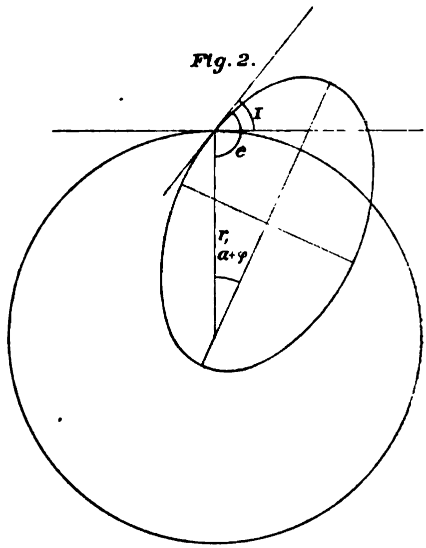



*Fig. 2.*




Hence $b = V_1 \sqrt{\frac{a}{g}} \cos \mathrm{I}$ (6); $b$ is therefore fully known.

An examination of the values of $a$ and $b$ shows that the greater $V_1$ the greater their values, since the denominators become smaller and smaller, while the numerators remain constant.

If in the values of $a$ and $b$, $V_1$ be 0, $b = 0$; that is, the projectile falls to the center of the earth.

Substituting in equation (1) for $\frac{4c^2}{K\,m}$ and $\frac{4c^2}{K^2 m^2}$ their values $\frac{b^2}{a}$ and $\frac{b^2}{agr_1^2}$ respectively, we have

$$r = \frac{b^2}{a + \sqrt{a^2 - b^2} \cos (\alpha + \varphi)}$$

which we recognize as the general polar equation of the ellipse, the pole being at the right-hand focus. As it is proposed in what follows to take the pole at the left-hand focus the equation should be written:

$$r = \frac{b^2}{a - \sqrt{a^2 - b^2} \cos (\alpha + \varphi)}.$$

But $(\alpha + \varphi)$ is the angle made by the radius vector with the transverse axis. To find this angle for the particular value $r_1$ of the radius vector

substitute $r_1$ for $r$ in the above equation and solve with respect to cos $(a+\varphi)$. We then have

$$\cos(a+\varphi)=\frac{ar_1-b^2}{r_1\sqrt{a^2-b^2}}. \tag{7}$$

Substituting for $a$ and $b$ their values, remembering that $\sin\epsilon=\cos \mathrm{I}'$ there results

$$\cos(a+\varphi)=\frac{gr_1-\mathrm{V}_1^2\cos^2\mathrm{I}}{\sqrt{(\mathrm{V}_1^4-2g\mathrm{V}_1^2r_1)\cos^2\mathrm{I}+g^2r_1^2}}. \tag{8}$$

If, now, the elevation I and the initial velocity $\mathrm{V}_1$ be given, the *direction* of *the transverse* axis with respect to $r_1$ is fixed, as is also the conjugate, and the lengths of the axes are known. The trajectory is, therefore, fully determined both in size and position.

If we refer the curve to rectangular co-ordinate axes, the origin being at the gun, and the axis of X horizontal for ranges, as is customary, there will result a very lengthy equation of the second degree, involving the second powers of X and $y$, their first powers, the product of their first powers, and an absolute term; an equation which it is it is inconvenient to discuss, but which is the most general equation of the trajectory in vacuo when referred to the rectangular axes mentioned.

We may, however, determine the range in the following manner:

$$\cos(a+\varphi)=\frac{ar_1-b^2}{r_1\sqrt{a^2-b^2}} \text{ and } \sin(a+\varphi)=\sqrt{1-\cos^2(a+\varphi)}.$$

$$=\frac{\sqrt{2ar_1-r_1^2-b^2}}{r_1\sqrt{a^2-b^2}};$$

but $a=\frac{gr_1^2}{2gr_1-\mathrm{V}_1^2}$, from which $2agr_1-a\mathrm{V}_1^2=gr_1^2$ and $2ar_1-r_1^2$

$$=\mathrm{V}_1^2\frac{a}{g}=\frac{b^2}{\cos^2\mathrm{I}};$$

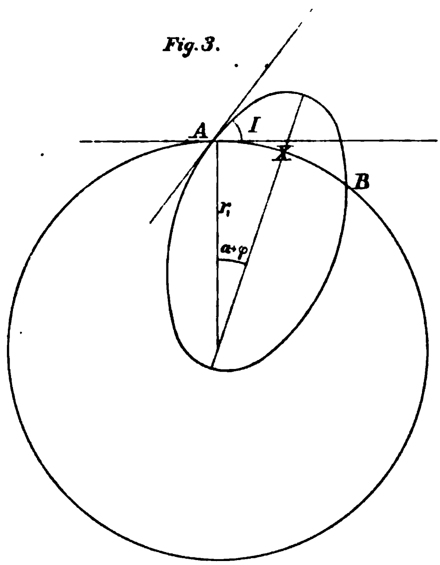
$$\therefore\ \sin(a+\varphi)=\frac{b\sqrt{\frac{b^2}{\cos^2\mathrm{I}}-b^2}}{r_1\sqrt{a^2-b^2}}=\frac{b^2\sqrt{\frac{1-\cos^2\mathrm{I}}{\cos^2\mathrm{I}}}}{r_1\sqrt{a^2-b^2}}=\frac{b^2\tan\mathrm{I}}{r_1\sqrt{a^2-b^2}}.$$

But $\tan(a+\varphi)=\frac{\sin(a+\varphi)}{\cos(a+\varphi)}=\frac{b^2\tan\mathrm{I}}{ar_1-b^2}$. Substituting for $b^2$ its value $\mathrm{V}_1^2\frac{a}{g}\cos^2\mathrm{I}$, there results $\tan(a+\varphi)=\frac{\mathrm{V}_1^2\cos^2\mathrm{I}\tan\mathrm{I}}{gr_1-\mathrm{V}_1^2\cos^2\mathrm{I}}=\frac{\mathrm{V}_1^2\cos\mathrm{I}\sin\mathrm{I}}{gr_1-\mathrm{V}_1\cos^2\mathrm{I}}$;

or, since $\sin 2\mathrm{I}=2\cos\mathrm{I}$, $\sin\mathrm{I}\tan(a+)\varphi=\frac{\mathrm{V}_1^2\sin 2\mathrm{I}}{2(gr_1-\mathrm{V}_1^2\cos\mathrm{I})}$, the second member of which equation contains only known quantities, viz, the initial velocity, the angle of elevation, and the radius of the earth at the firer's position.

The range as measured on the surface of the earth is the arc AB, Fig. 3, which we will represent by X. To find this arc we have tan

*Fig. 3.*




$(a + \varphi)$ as just determined, whence $(a + \varphi)$ becomes known. If now this angle be doubled we shall have $360^\circ : 2(a + \varphi) :: 2\pi r_1 : X$, whence

$$X = \frac{\pi r_1 (a + \varphi)}{90^\circ}, \text{ or } X = \frac{\pi r_1}{90^\circ} \tan^{*} - 1 \frac{V_1^2 \sin 2I}{2(gr_1 - V_1^2 \cos^2 I)}.$$

For the purpose of comparing the range as deduced by this formula with that given by the parabolic equation (Benton's Ordnance and Gunnery, page 397), an angle of elevation of 45° and an initial velocity of 1,500 feet per second were assumed, $r_1$ and $g$ being taken as 4,000 miles and 32.16 feet, respectively. By the former the range was found to be 23,434.6, and by the latter 23,320.1 yards, a difference of only 114.5 yards. The maximum range, as in the parabolic equation, is given by an angle of 45°, tan $(a + \varphi)$ being greatest for this value, and therefore $(a + \varphi)$, and consequently the range.

* Read the arc whose tangent is $\frac{V_1^2 \sin 2I}{2(gr_1 - V_1^2 \cos^2 I)}$.

# APPENDIX 35.

## REPORT ON THE MANUFACTURE AND USES OF FILES AND RASPS.

BY CAPT. D. A. LYLE, ORDNANCE DEPARTMENT, AND SAMUEL W. PORTER, MASTER ARMORER, NATIONAL ARMORY.

(Twenty-nine plates.)

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## PART II.

### *Rasps.*



## PART III.



## PART IV.



## PART V.

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### PLATE II.

Diagram of cross-sections of standard sizes of regular files. The figures in the diagram indicate the length of the file in inches. (Kearney & Foot.)

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Figures of standard six-inch files of various kinds. (Kearney & Foot.)

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Figures of standard six-inch files of various kinds. (Kearney & Foot.)

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Figures of standard six-inch files and rasps of various kinds. (Kearney & Foot.)

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Showing sections of Nicholson File Company's rectangular files of various kinds. The figures on the section show the length of the file.

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Showing the circular, triangular, and miscellaneous sections of Nicholson's files, with their corresponding lengths.

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Showing the cut of coarse and bastard brass files, lead-float, finishing second cut ("new" or "skew-cut"), and bread-rasp.

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PLATE XX.

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The above two diagrams also show the effect that would be produced by grinding the chisel to a sharp knife-edge, thus increasing the tendency to clog or "pin."
FIG. 5.—Enlarged diagram, showing the effect of blunting the edge of the chisel, so as as to prevent "clogging," without impairing the shape and strength of the teeth.
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Fig. 8.—Showing a file-carrier in which the file is mounted after the manner of a frame-saw.

PLATE XXI.

FIG. 1.—Card & Studley's file cutter.
FIG. 2.—Rotherham & Holden's file-cutting machine.

PLATE XXII.

FIG. 1.—Reciprocating filing-machine, mounted after the manner of a jig-saw.
FIG. 2.—File-stripping machine.

PLATE XXIII.

FIG. 1.—A, end elevation of file-cutter's chisel; B, side elevation of same chisel.
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FIG. 1.—Rear elevation of file-cutter's hammer without handle, used at National Armory.

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### PLATE XXV.

FIGS. 1 to 3, and 5 and 6.—Side elevations of file-cutter's hammers, with their corresponding weights, used at National Armory.

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FIG. 5.—Isometrical projection of oil-cup and roller, used at National Armory.

### PLATE XXVII.

FIG. 1.—Front elevation of furnace used for heating files for hardening.

FIG. 2.—Section of furnace and pot for containing melted lead, used for heating files for hardening.

FIG. 3.—Plan of furnace.

FIG. 4.—Method of straitening files.

FIG. 5.—Method of straitening files after they have become cold.

### PLATE XXVIII.

FIG. 1.—Shows the shape of the file desirable for a concave surface.

FIGS. 2 and 3 and 4.—Show the difficulty experienced in filing a narrow surface flat. In Fig. 2, at the beginning of the stroke the right hand having a greater leverage than the left, the file will tend to assume the position shown in the figure, and will cut more off the right-hand edge of the work. In Fig. 3, the leverage being about equal at the two ends of the file, it will tend to assume a horizontal position, as shown in the figure. This represents the position of the file at the middle of the stroke. Fig. 4 represents the position of the file at the end of the stroke; the left hand having the greater leverage, the file tends to cut more from the left-hand edge. The effect of these three positions is to leave the work rounding, instead of flat, and the work will present the appearance as shown in C, Fig. 4. In the three diagrams above cited the positions of the file are exaggerated in order to show the rolling action of the file as exhibited in the hands of inexperienced workmen.

FIG. 5.—Shows the method of filing a slot in a spindle, the work being suspended upon the centers of the lathe, in order that it may oscillate so as to compensate for the natural swaying or rolling motion of the file in the hands of the workman.

FIG. 6.—Shows the method of proving a filed beveled edge by means of a bevel gauge with a movable blade.

FIG. 7.—Shows the method of proving a filed rear end of a receiver for Springfield rifle with flat gauge:
A. Rear end of receiver.
B. Gauge.

FIG. 8.—Shows the method of proving the depth of a filed slot by means of a "depthing gauge":
A. Work.
B. Gauge.

FIG. 9.—Shows gauge and method of proving filed hammer for Springfield rifle:
A. Hammer.
B. Gauge.

PLATE XXIX.

FIG. 1.—Shows the effect of filing a concave groove with a file having less curvature than the groove.

FIG. 2.—Shows the effect of filing a concave groove with a file having greater curvature than the groove, in which case the file only touches the work along one element of the grooved surface, instead of two, as shown in Fig. 1; therefore the method as shown in Fig. 1 is preferable until the work is reduced nearly to the finished size.

FIG. 3.—Shows a case in which the file and the groove have the same curvature. This would be the easiest and quickest method of filing were it not for the irregularity of the teeth, which leave ridges in the work, unless, during every stroke, the file is rotated by twisting the wrist to and fro. In these three cases the axis of the file is sensibly parallel to the axis of the groove, as shown by the dotted line in Fig. 4.

FIG. 5.—Shows convex work in which the file may be applied to the surface parallel to the axis as shown in the dotted line P P, or transverse to this axis as shown by the dotted line T T.

FIG. 6.—Shows the general method of filing convex work. The latter is fixed obliquely in the vise, and the file first used transversely for a few strokes at an inclination of about 30° to the horizontal line, as shown at *a*, so as nearly to agree with the straight side of the work. The succeeding strokes of the file would be directed in the several directions from *a* to *c*, inclusively, and then finished by a series of rounding strokes swinging over the whole arc from *a* to *c*. The position of the work is then changed in the vise, and the opposite side is filed in a similar manner. A more exact, and slower, method would be to file parallel to the axis, and do the rounding by the twist of the wrist.

FIG. 7.—Shows a short rectangular mortise and the right-angled triangular templet A, with which the filing is proved.

FIG. 8.—A. A cylindrical steel plug, with a longitudinal slot in one side, used to guide the file in cutting key ways in the axial holes of wheels.
B. The form of file cut only on one edge, to be used in connection with the the cylindrical plug A, for filing key ways in the axial holes of wheels.

FIG. 9.—A. Receiving gauge for lock plate for Springfield rifle.
B. Lock plate, or work to be filed to fit the above-mentioned gauge.

FIG. 10.—Gauge for proving the filed dimensions of the rear-sight leaf for the Springfield rifle; the shaded portion represents the rear-sight leaf and its sections.

## ACKNOWLEDGMENTS.

The writers desire to acknowledge their indebtedness to Mr. Nicholson's "*Treatise on Files*"; to Knight's "*Mechanical Dictionary*"; to "*Johnson's New Illustrated Universal Cyclopædia*," the "*Encyclopædia Britannica*," and to Mr. James D. Foot's "*Descriptive Catalogue of Files*," for much valuable information. The materials gathered from these sources have been incorporated in the following pages. Many of the illustrations have been taken from the works of Messrs. Knight, Nicholson, and Foot. The other drawings have been made by Mr. C. A. Emery, National Armory.

The thanks of the undersigned are due to C. A. Emery, C. E. Bailey, Wm. G. Chamberlain, E. C. Wheeler, and James O'Niel, of the National Armory, for assistance in the preparation of this report. We are under special obligations to Mr. George Kemater, file-cutter of the National Armory, for valuable suggestions and information in regard to the manufacture of files.

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*Springfield, Mass., July* 29, 1881.

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# PART I.

## FILES.

### *Definition.*

A file is a steel instrument used for abrading or smoothing surfaces. It has sharp raised cutting edges or teeth upon its surface, made by the indentations of a chisel. It is a tool used for shaping, smoothing, or finishing all kinds of material used for construction. The size and shape of the file are determined by its intended use. The direction and number of the cutting edges and the magnitude and distribution of the teeth vary "with the nature of the material and the degree of smoothness of the surface which the file is required to produce."

"The forms given to files, as well as their shapes and sizes, are almost numberless." Most files are "tapered;" the "blunt" are nearly parallel with the largest section near the middle; a few are parallel.

## ANTIQUITY OF THE FILE.

The file appears to be one of the most ancient instruments used by man. In the Bible (I Samuel, xiii, 21) is found the following reference to files: "They had a file for the mattocks, and for the coulters, and for the forks, and for the axes, and to sharpen the goads."

There are also cases cited where savage tribes or nations have employed coral, dried shark skin, and stone for the purpose of abrading surfaces after the manner of a file.

A glance at the synonymy given below shows a remarkable similarity in the terms used by different languages to express the word "file," and proves that this instrument has been in general use among the nations of the old world for centuries past.

## SYNONYMY.

| | |
|---|---|
| Greek | Rinae. |
| Hebrew | P'tzeerah or Petsirah. |
| Latin | Lima. |
| Italian | La lima. |
| Spanish | La lima. |

| | |
|---|---|
| French | La lime. |
| Chinook jargon | La-leem (from the French *la lime*). |
| Polish | Pilnik (?). |
| Icelandic | Thiöl. |
| Danish | Fīl. |
| Swedish | Fīl. |
| Dutch | Vyl. |
| Old High German | Fīla. |
| High German | Vīle. |
| New High German | Feile, *f.* |
| Anglo-Saxon | Feol. |
| English | File. |

## CLASSIFICATION.

Files have three distinguishing features: their size, their cut, and their kind or name.

It is very difficult to give a satisfactory classification, since arbitrary rules are followed in different localities, and even in different shops in the same locality. Again, the several trades have imposed, in many cases, their own peculiar nomenclature. The following has been adopted as the best method that could be devised at the present time, and follows Knight's tables as closely as possible:

Files are graded by their:
- I. Size.
- II. Cut:
  - 1. Character of teeth.
  - 2. Fineness of cut.
- III. Shape.
- IV. Peculiarities of form not shown in section.
- V. Purpose.

## I.—SIZE.

The lengths of files vary from three-quarters of an inch (watchmaker's) to two or three feet (engineer's).

The file is composed of:
- 1. The body:
  - 1. Heel.
  - 2. Point.
- 2. The tang.

The body comprises the cutting portion of the instrument, and has its extremities designated by the terms *heel* and *point*. The heel is that part of the file adjoining the tang. The point is the opposite end of the file farthest from the tang.

In speaking of the length of a file it is always understood that it is the length of the body that is meant, except in cases of some rasps and double-ender files that have no tangs, when the total length is the one given.

The tang is the spike-shaped projection on the rear end of the file fitted for insertion in the handle. Its size and shape is proportional to the dimensions of the file and the kind of work to be performed. The lengths of files appear to bear no fixed relation to either their width or thickness, even when of the same kind.

## II.—THE CUT.

1. Character of teeth:
   1. Single cut or float—having but one row of teeth.
   2. Double cut—having two sets of teeth crossing obliquely.
   3. Rasp—having detached teeth made by a punch instead of a chisel.

2. Fineness of teeth:
   1. Rough cut.
   2. Middle cut (*coarse* of Nicholson).
   3. Bastard.
   4. Second cut.
   5. Smooth.
   6. Superfine or dead-smooth.

### 3. Approximate number of cuts in an inch of length of files. (*Knight.*)

| Fineness of cut. | Length of files in inches. | | | | | |
|---|---|---|---|---|---|---|
| | *4 inches.* | *6 inches.* | *8 inches.* | *12 inches.* | *16 inches.* | *20 inches.* |
| Rough | 56 | 52 | 44 | 40 | 28 | 21 |
| Bastard | 76 | 64 | 56 | 48 | 44 | 34 |
| Smooth | 112 | 83 | 72 | 72 | 64 | 56 |
| Superfine or dead-smooth | 216 | 144 | 112 | 88 | 76 | 64 |

## 4. General description.

### 1. *Character of teeth.*

1. *Single cut.*—(Plate VII.)—In single-cut files the blanks have a single course of chisel cuts across their surfaces parallel to each other. These parallel cutting edges make an angle of from 5° to 20°, in different files, with a horizontal line perpendicular to the longer axis of the file. In this class the cutting edges are unbroken.

2. *Double-cut.*—(Plate VIII.)—These files have two courses of chisel cuts crossing each other at an angle. The first course is called the overcut and its indentations make an angle varying from 35° to 55° with the horizontal lines perpendicular to the axis. The second course crosses the first and is generally finer than that course. It is called the *up-cut* (or sometimes the top-cut or cross-cut), and makes an angle varying from 5° to 15° with the perpendicular lines above mentioned. The effect of these two courses of chisel-marks is to cover the surface of the file with teeth which incline toward the front or point. These teeth are diamond or lozenge shaped and act as small planing tools when pushed over a hard surface. "The *double cut* is applied to most of the files used by the machinist, and in fact to much the larger variety in general use."

3. *Rasp cut.*—(Plate X.)—See *infra*, under "Rasps."

### 2. *Fineness of cut.*

(Plates I, VII, VIII, and X.)

1. *For single-cut files.*—For these files the gradations of coarseness are made known by the application of the terms *rough*, *coarse or middle cut*, *bastard*, *second cut*, and *smooth*.

The *rough* and *coarse* or *middle cut* are applied to files designed for use upon soft metals—lead, pewter, &c., and upon wood. Bastard and second cut are used on files intended for sharpening the thin edges of saw-teeth, which are very destructive to the delicate teeth of double-cut files. The *smooth* is applied to *round* and the backs of *half-round* files, rarely to others.

2. *For double-cut files.*—For these the degree of coarseness is designated by the terms coarse or middle cut, bastard, second cut, smooth, and dead-smooth. The double cut is used upon the majority of machinist's and gunmaker's files and the greater part of those in general use. The dead-smooth double-cut files are very similar to the *smooth*, except that they are much finer.

3. *For rasp cut.*—The grades of cut used for rasps are coarse or middle cut, bastard, second cut, and smooth. For further particulars, see "Rasps."

### 5. GRADES OR CUTS OF LEADING REGULAR FILES.

Below will be found the number of cuts to the inch in standard files as given by Mr. James D. Foot, New York. Mr. Foot says: "As a matter of convenience the grade of the tooth is given by counting only one of the cuts of the file, and we take for this the 'over-cut' or first cut." The number of teeth given are those corresponding to the running inch (of length), except the wood rasp and cabinet rasp, whose isolated teeth are punched or raised, in which cases the exact number of teeth to the square inch is given. In describing the several grades of cuts Mr. Foot takes as his standard his 12-inch file, using an inch section from the middle of the file.

FILES.

| Kind of cut. | Number of teeth to the running inch. | Remarks. |
|---|---|---|
| Rough | 22 | |
| Bastard | 32 | |
| Second cut | 44 | |
| Smooth cut | 68 | |
| Dead smooth | 120 | |
| Mill, bastard | 36 | A series of diagonal teeth. |
| Mill, second cut | 44 | do. |
| Taper saw, single cut, second cut | 50 | do. |

RASPS.

| Kind. | Cut. | Number of teeth to the *square* inch. | Remarks. |
|---|---|---|---|
| Wood rasps | Bastard | 105 | Punched teeth. |
| Cabinet rasps | Smooth | 300 | do. |
| Do | Second cut | 168 | do. |

## III.—Shape.

(Plate XIX.)

Shape derived from the—

- 1. Square are—
  - *a*. Square file.
    - 1. Parallel. } Sometimes with safe side.
    - 2. Taper. } Sometimes with safe side.
  - *b* ..............
    - 1. Cotter file, when large.
    - 2. Verge or pivot file, when small.
  - *c*. Flat file ...
    - 1. Pottance file, when small.
    - 2. Pillar file, when narrow.
  - *d* ..............
    - 1. Equaling, clock-pinion, or endless-screw file, when parallel.
    - 2. Slitting, entering, warding, or barrel-hole file, when taper.
  - *e*., *f*. ..........
    - 1. Shouldering file, or French pivot file.
    - 2. Parallel V file.
  - *g* ................Nail file for finger-nails.
  - *h* ..............
    - 1. Pointing mill-saw file.
    - 2. Round-edge file.
- 2. Circle are—
  - *i* ..................Round, gulleting, rat-tail file.
  - *k* ..................Frame-saw file. } Nicking file. Piercing file. Round-off file.
  - *l* ..................Half-round file. } Nicking file. Piercing file. Round-off file.
  - *m* ..................Cross file; double half-round file.
  - *n* ..................Oval file.
  - *o* ..................Balance-wheel or swing-wheel file, cut on convex side only.
  - *p* ..................Swaged file, for finishing brass moldings.
  - *q* ..................Curvilinear file.
- 3. Triangular are—
  - *r* ..................Triangular, three-square, or saw file.
  - *s* ..................Cant file, for filing inside angles of 120°.
  - *t* ..............
    - 1. Banking or watch-pinion file, when parallel.
    - 2. Knife-edge file, when taper.
  - *u* ..................Screw-head, feather-edge, slitting file.
  - *w* ..................Valve file.
  - *x* ..................Triangular and half-round file.
  - *y* ..................Double or checking file, for gunsmiths.
  - *z* ..................Double or pencil-sharpening file.

## IV.—Peculiarities of Form not Shown by Section.

Peculiarities of form not shown by section.

1. Taper; thinner toward the point.
2. Parallel; the same dimensions throughout the length.
3. Blunt; a grade between taper and parallel.

## V.—Purpose.

Files are sometimes classed according to the purposes for which they are used, as mill files, hand-saw files, &c.; or the trade by which employed, as watchmaker's, gunsmith's, machinist's, engineer's, cabinet-maker's, combmaker's, sculptor's files, &c. Some of the files most commonly used are here enumerated.

For convenience the files are grouped in classes, according to the character of their cross-sections.

### 1.—*With cross-sections derived from the square.*

(Plates I, II, and VI.)

*Mill files.*—Used for sharpening mill saws, mowing-machine knives, and plows; in machine shops, for lathe work, drawfiling, and finishing brass or bronze castings.

*Mill blunt*—(Equaling, of some makers).—Used in machine shops and for filing narrow mortises.

*Flat files.*—For general use.

*Flat equaling.*—Used for finishing broad mortises, as in pitman heads to prepare for gib and key.

*Hand.*—Finishing flat surfaces, used by machinists and engineers; has one safe edge.

*Hand equaling.*—For same purpose as flat equaling.

*Pillar.*—Used to finish narrow work and on some classes of gun work.

*Slotting file.*—Filing grooves for cotters, keys, or wedges.

*Cotter taper.*—Special work—rarely called for.

*Cotter equaling.*—For same purposes as *flat-equaling* files and slotting files—seldom called for.

*Square.*—General uses; for enlarging rectangular or square apertures.

*Square blunt.*—Used by engine builders, in railroad shops, and ship-yards for rough work in finishing and enlarging mortises, keyways, or splines when of considerable length.

*Square equaling.*—For the nicer work in finishing keyways, splines, &c.

*Warding files.*—Used by locksmiths in filing ward notches in keys, also by jewelers and machinists.

*Warding blunt.*—For same purposes as *warding taper*, and by specific trades.

*Warding, round-edge, or drill files.*—For enlarging or rounding the bottoms of slots where the round file would be too frail; for filing twist drills, and other similar purposes.

### 2.—*With cross-sections derived from the circle.*

(Plates I, II, and IX.)

*Round files.*—For enlarging round holes and finishing "filled in" angles.

*Round blunt.*—For heavy work in ship-yards, railroad shops, engine building, and bridge building.

*Gulleting file.*—Extending the gullets of teeth in the gullet-tooth or briar-tooth saws.

*Half-round files.*—In general use.

*Half-round wood file.*—Used by wood-workers generally, and on coarse brass work.

*Hook tooth file.*—Sharpening the teeth of "hook-tooth saws."

*Pit-saw file, frame-saw file.*—In filing the teeth of pit or frame saws.

*High-back files.*—For special purposes in place of half-round or round files.

*Cabinet files.*—Used by cabinet, saddle-tree, pattern, and last makers, gun-stockers, and wood-workers generally.

### 3.—*With cross-sections derived from the triangle.*

(Plates I, II, and IX.)

*Three-square files.*—Used in rolling mills and machine shops, and for filing internal angles less than a right angle; for cleaning out square corners, filing up taps, cutters, &c.

*Three square blunts.*—In machine shops, for filing up milling machines and cutters for metals.

*Hand-saw taper, single cut.*—For sharpening hand saws. A file of the most general household and workshop distribution.

*Hand-saw taper, double cut.*—Filing fine-teethed hand and back saws, and the hard "hack-saws" of metal-workers.

*Hand-saw blunt.*—Not in general use.

*Band-saw blunt.*—Used for filing the teeth of band-saws.

*Cant files.*—For filing the inner angles of spanners or wrenches for hexagon bolt heads and nuts.

*Lightning files.*—For filing "lightning saws" and the M-shaped teeth of crosscut saws.

*Knife files.*—Used in filing the inner angles of sear and main springs on gun-work and similar shapes.

*Knife blunts.*—For finishing the teeth of small-gear wheel patterns, for beveling the sides of narrow grooves, enlarging slots in screw-heads, &c.

*Gin-saw files.*—For filing the teeth of saws used in cotton-gins.

### 4.—*Miscellaneous files.*

(Plates I, II, and IX.)

*Cross files.*—Used where two different curvatures are required.

*Feather-edge files, curry-comb files.*—Little used by the general mechanic. Formerly used for filing feather springs or sear springs of gun-locks, and for teeth of curry-combs; but few now made; have been superseded by the knife file.

*Reaper files.*—For sharpening the knives of reaping and mowing machines.

*Tumbler files.*—Formerly used for filing tumblers for gun-locks—rarely called for now.

*Lead float—(Nicholson File Company).*—For filing lead; used by plumbers and workers in lead, pewter, and soft metals, and to some extent for bone, ivory, and horn work.

*Brass coarse—(Nicholson File Company).*—For very rough work on softer metals; on brass and bronze castings and ends of brass rods; also used on wood work.

*Brass bastard—(Nicholson File Company).*—For finishing brass, bronze, copper, and the softer metals.

*Finishing second cut—(Nicholson File Company).*—Light finishing on steel or iron, on large surfaces.

*Slim hand-saw taper—(Nicholson File Company).*—To replace hand-saw files; it is longer and has more sweep.

*Double-ender hand-saw—(Nicholson File Company).*—A substitute for the hand-saw file.

*Roller file.*—In filing the flutes of feed-rollers in cotton spinning machinery.

NOTE.—For general description of files, rasps, and terms used, see "Glossarial Description."

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## MANUFACTURE OF FILES.

### I.—MATERIAL.

The material generally used for files is cast-steel. Blister-steel is occasionally used for the larger and rougher varieties of files. Files

should be and are usually made of the best material, and great care should be taken to select steel that is uniformly and highly converted. Files of peculiar shapes for certain purposes, as for sculptors, are sometimes made of good wrought-iron and case-hardened. The cast-steel generally employed is known as "crucible steel," in contradistinction to "Siemens-Martin" or "Bessemer" steel, and until within a short time was imported almost exclusively from Sheffield, England. American steel is now being used in this country, and it is said to be of as good quality and as uniform as the English. Mr. Nicholson says "that our (Nicholson File Company's) experience and tests have demonstrated that the American steel, as a rule, contains a better quality of material than we formerly obtained in the English." Steel for files is drawn out in bars of from 8 feet to 12 feet in length, having as nearly as possible the requisite cross-section both as regards size and shape. From these bars are cut the proper lengths for file blanks.

## II.—File blanks.

Whether the files be cut by hand or by machine, the steel must first be formed into proper shape for the operation of cutting. In order to secure good results, great care must be exercised in the preparatory operations, as the steel may be so injured or the shapes so irregular that after cutting and hardening the files will be found to be of inferior quality or else unfit for use.

The preliminary operations are four (4) in number, viz:

1. Forging.
2. Annealing.
3. Grinding,
4. Draw-filing.

After passing through the several processes the roughly-formed files are known as "file blanks." The blanks are divided into classes, depending upon the stage of preparation, as follows:

1. Black blanks.
2. Gray blanks.
3. Bright blanks.

The first class indicates the forged stage, the second the annealed, and the third the ground stage. It has been the custom of centuries to form these blanks by hand, but latterly the aid of machinery has been successfully sought. No doubt the prejudice of trades' unionism has been largely responsible for the slow advancement in the art of preparing blanks. The prepared blanks are often sold to the small makers, who have few or no facilities for their rapid and economical production.

## III.—Preparing the file blanks.

1. *Forging.*—The blanks are forged from bars that have been carefully prepared by tilting or rolling the bar as near to the required section as practicable. Dies or formers may be used with advantage in forging. The forger should work the metal at as low a temperature as possible, not above a blood-red heat. Extra care should be taken to procure good fuel. Coke made from coal free from traces of sulphur is generally employed. Greater uniformity in the shape of the point and body is obtained when the forging is done by machinery, and the steel is less liable to be injured than in the slow and tedious hand process. One great advantage claimed for power forging is the great uniformity secured in the shape of the tangs, thus enabling the consumer to make

a considerable saving in handles. The junction of the tang and body should be curved surfaces instead of sharp, angular corners, as then the files are less liable to be weakened by fire-cracks or "checks," and are less apt to be broken. The tangs should be so made that the handles may be readily interchangeable in the case of files of about the same size and weight.

2. *Annealing.*—After forging, the file blanks are very carefully annealed by being first packed in dry sand in iron boxes or retorts, when the lids are luted down with fire-clay to prevent the access of air, after which they are placed in the annealing oven, where the heat is gradually increased until the retorts assume a cherry-red color. The retorts are then removed from the oven and allowed to cool slowly before unpacking. Cheap grades of files are annealed in ordinary annealing ovens without packing, which exposes them more or less to the action of the air. The operation of annealing is of vital importance, since the forger usually throws the blanks while hot upon the earthen floor of the shop where they are exposed to the varying currents of air, and cool unequally, thus giving them an uneven temper. Careless annealing affects the quality of the hardened file and has its influence upon the operations of cutting and grinding. Different makers have different methods of constructing their ovens, especially in cases where the blanks are piled in quantities in the oven without being packed in retorts; the object in all cases being to obtain uniformity of heating throughout the mass of blanks. After cooling the blanks are straightened or "smithed" by means of a hand-hammer, when they are ready for grinding.

3. *Grinding.*—When straightened, the blanks are rendered clean and accurate in form by means of grinding. Filing was formerly employed to reduce the blanks to size and to remove the scale left from the forging and annealing processes, but latterly grindstones have come into general use for this purpose, whereby the work is more expeditiously and cheaply performed. The grinding is generally performed by hand, though machinery is gradually coming into use for this purpose, except for the smaller-sized and irregular-shaped files, which are always ground by hand. For some of the coarser files the blanks are slightly greased after grinding, when they are ready for cutting.

4 *Draw-filing.*—Though the process of grinding may leave the surface apparently true as far as the eye is able to discover, it will be found that the surfaces are marred by slight irregularities. The operation of draw-filing, or "stripping," as it is termed by file-cutters, is resorted to for the purpose of correcting these slight irregularities. If this is not done the irregularities are multiplied in the points of the teeth, which will greatly impair the efficiency of the file. The blanks for the fine-cut files should be very carefully draw-filed in order to produce as perfect a surface as possible. Mr. Nicholson claims that this laborious operation is often "slighted by the workmen at the expense of the quality of the file." He uses machinery for "stripping," and claims much greater accuracy than can be obtained by manual labor. After draw-filing, the blanks are slightly greased before being sent to the cutters.

## IV.—File cutting.

Before passing to the consideration of file cutting, either by hand or by machinery, it will not be amiss to say something in regard to the formation and arrangement of the teeth of files. The examination of the extremely small points which form the teeth is attended with no

little difficulty even where the eye is aided by a powerful glass. There can be no doubt but that the form of the teeth varies, and that this variation, together with the arrangement and grouping of the teeth, constitutes an important element in determining the efficiency of the file. Teeth of files are formed by chisel cuts or indentations that force the metal above the plane surface of the blank. The shape and height ot the teeth depend upon—

1st. The force of the blow upon the chisel.

2d. The inclination of the chisel to the plane of the blank.

3d. The angles made by the cutting faces of the chisel.

The first affects the height of the tooth, the second its shape. If the inclination of the chisel to the plane of the blank be 90°, or the chisel be held vertically, the faces of the indentation will form the two sides of an isosceles triangle, as shown in Fig. 3, Plate XX.

If the inclination be too great the cutting face of the tooth will be undercut or "hooking," as represented in Fig. 4, Plate XX.

It is evident that any intermediate angle of inclination of the cutting face may be obtained by simply varying the inclination of the chisel between these two extremes. Similar changes may be produced by changing the angle of the faces which form the edge of the chisel by grinding. Some hand-cutters have claimed that the different angles of the faces of the teeth were caused by the "peculiar movement given to the chisel" at the instant of striking the blow with the hammer, and by a "curved or drawing blow," but a moment's thought will render it apparent that these are the results of well-known mechanical laws. It is also claimed by some that a good tooth can only be produced by a chisel ground to a sharp knife-edge, but they seem to forget that it is the top of the tooth, not the *bottom*, that does the cutting. When the proper shape of the top of the tooth has been secured, the base and bottom of the indentation should be constructed with a view to obtain the necessary strength of tooth and the proper clearance. The latter is of special importance in order to prevent "pinning," which is the cause of a great deal of trouble and annoyance to the workman on account of the "channeling" or "grooving" produced thereby, especially when the finer files are used. The principal cause of "pinning" is the acuteness of the angle forming the bottom of the chisel-cut which permits the abraded particles of the material, or filings, to wedge in the tooth so tightly that it is often difficult to remove them. This effect can be partially avoided by slightly blunting the cutting edge of the chisel, provided the form of the tooth be not impaired. The edge of a chisel to produce such an effect is shown in Fig. 5, Plate XX.

The edge of the face that makes the cutting face of the tooth is made sharp to give a keen point to the tooth. This form of chisel will largely obviate the tendency to "pin," and will not destroy the general shape of the tooth. This form of chisel-edge is, however, somewhat difficult to use by the hand-cutter, but in machine cutting it apparently presents no special difficulty. When the chisel gets dull or rounded by use it will not make a clear cut, but will round the face slightly, producing what are called "caps" to the top of the teeth. This effect is shown in Fig. 6, Plate XX.

This effect will appear in both machine and hand cutting, and is more frequently seen in the coarser cuts. It can only be avoided by proper care of the chisels. These "caps" are very small and naturally crumble or break off the first time the file is used, so they do not necessarily render the file useless.

Figs. 3, 4, 5, and 6, Plate XX, are of course highly magnified, in order

to show more clearly the shape and angles of the teeth. The faces of the teeth of fine files generally slope *back* from the perpendicular from 2° to 5°, and on the coarse grade of files from 5° to 10°. Were this not so it would be almost impossible to keep the filings from wedging into the spaces between the teeth, or "pinning."

1. *Cutting by hand.*—When ready for cutting the blanks are carried to the operator, who is seated with a square stake or anvil in front of him. He places the slightly greased blank upon the anvil with the shank or tang pointing toward him, where it is held by two leathern straps passed over its ends and held fast below by the foot after the manner of a stirrup. In his left hand is held a short cold-chisel whose edge is straight and *always* exceeds in length the width of the file blank. His right hand wields the peculiarly shaped hammer used for this purpose. He places the chisel on the blank near the point, inclining it slightly from him with the edge making the proper angle with the middle line or axis of the blank. He strikes the chisel a sharp blow with the hammer, which makes an indentation and throws up a slight ridge of steel on the side next the tang. The chisel is then removed to the uncut surface and slid from the cutter until it brings up against the ridge just made, when another blow is struck, forming a second ridge parallel to the first. This method of procedure determines the positions of the consecutive cuts with accuracy. It is repeated until the whole surface is gone over. The workman delivers the blows with a force as uniform in intensity as possible. From sixty to eighty cuts are made per minute. The above operations fill one side of the blank with parallel ridges that constitute the first course of cuts, after which, if the file is to be double cut, the operator proceeds to make the second course, whose cuts are generally finer than the first. The surface is now covered with diamond-shaped teeth inclined toward the point of the file. If the file be flat and is to be cut on the other side, it is turned over and a thin plate of lead or pewter placed under it to protect the teeth from injury. Triangular and other files are placed in grooves of lead to support them while cutting. In cutting round and half-round files the straight chisel is placed tangent to the surface and slightly inclined to the direction of the axis as well as to the front. These curved faces require eight, ten, or more courses to complete the file. Before making the second cut a fine file is passed lightly over the surface to smooth it for the second or up-cut course, in order that the chisel may glide easily over the surface. The second set of cuts usually makes a large angle with the first, the two sets making "angles of about + 50° and — 80°, respectively, with the middle line of the file." After finishing both sides the edges are cut if required.

The spacing of the teeth is regulated by the height of the ridge thrown up by the chisel in making the indentation, and since this ridge in turn depends upon the force of the blow from the hammer, it follows that the regularity of the work must depend upon the skill of the workman, and must vary with his habits, temper, and physical condition. Hence it will be seen that the teeth of the files must possess more or less irregularity. A certain degree of irregularity is desirable to prevent the "chattering" or "grooving" that would result from files cut with exactly equal spaces between the teeth, and having the latter all the same height, which they would have if the metal was perfectly homogeneous and the blows of the hammer equal in intensity. The more skillful the workman the more nearly will his work approximate to that "controllable regular irregularity" which is so essential to the excellence of the file.

2. *Cutting by machine.*—The several machines designed for file cutting have generally tended to produce "*equidistant spacing in the teeth*" from the point to the heel of the file. This extreme regularity in double-cut files forms channels in the work which are counterparts of the equidistant grooves in the files. In single-cut files a "chattering and jarring sensation" is produced by the same cause. The exact regularity and uniformity of the teeth, both in their height and their distance apart, allows all or nearly all of the teeth to become engaged simultaneously with the elements of the surface upon which they are employed. It is evident, since the number of teeth which take hold of the work is much greater than in the case of the irregular teeth of hand-cut files, the workman must exert not only greater force to push the file forward, but greater pressure upon the file to make it take hold upon the material, or "bite," as it is termed. If the increased pressure be not applied the file will slide over the surface without cutting, due to the increased number of points of contact. The sliding effect is especially noticeable upon the broad flat surfaces where the whole body of the file comes in contact with the work, and gives rise in the mind of the workman to the belief that the teeth are dull. The machine-made files, with equidistant spacing, answer very well for certain classes of work, though they increase the labor of filing, but as yet they have not supplanted the irregularly spaced hand-made or Nicholson increment-cut files. Raoul's machine was applied (1800) to making watchmaker's files, which were said to be "less liable to clog and pin when in use" than the hand-cut files. The small Swiss and French files for the use of dentists, watch and clock makers are said to be made by machinery.

3. *Nicholson's "increment-cut" file.*—This file is made by machinery and is claimed to fulfill the conditions requisite for a perfect file, and to overcome the grave objections to the equidistant spacing of the ordinary machine made files.

The arrangement of the teeth of this file is thus described by Mr. Nicholson:

1. "The rows of teeth are spaced progressively wider, from the point toward the middle of the file, by regular increments of spacing, and progressively narrower, from the middle toward the heel, by regular decrements of spacing."

2. "This general law of the spacing of the teeth is modified by introducing, as they are cut, an element of *controllable irregularity* as to their spacing; which irregularity is confined within maximum and minimum limits, but is not a regular increment or decrement."

3. "In arranging the teeth of files so that the successive rows *shall not be exactly parallel*, but cut slightly angularly with respect to each other—the angle of inclination being reversed (during the operation of cutting) as necessity requires."

The above characteristics produce files that have a "shearing cut," for the points of no three consecutive teeth in any longitudinal row of a double-cut file are in the same straight line. This arrangement prevents cutting channels or furrows in the work, and enables the latter to be done more rapidly and smoothly than when the teeth are regularly disposed upon the file. The advantages of the "increment-cut" file are set forth in "Johnson's New Universal Cyclopædia," as follows: "The difference between this and the perfect regularity of other kinds must be apparent, particularly in double-cut files; as in the one case the file cut with such extreme regularity, when put to use, will, in the first inch of its movement, produce channels or grooves, and these grooves will continue to be made deeper as the file is shoved along, thus producing

that "grooving" and "chattering" so often complained of; while in the increment-cut file, the grooves made by the movement of the file the first inch will have their sides cut away as the file is moved toward the tang or handle, and *vice versa;* and while it is cutting as fast as its points permit, it is also said to cut smoother than the best hand-cut file of the same coarseness. The irregularity spoken of consists not only in the space between the teeth, but also in the height of the teeth themselves. The object of having the teeth of different heights is to admit of their being held down to the work with less effort on the part of the workmen."

Mr. Nicholson, who is an advocate of the machine-made "increment-cut" file, draws the following conclusions from his discussion upon the teeth of files:

1. "That there are no peculiarities in the formation or shape of the tooth of a file, as made by hand, that cannot be made by machine."

2. "That teeth can be so formed by machinery, without impairing their general shape, as to largely prevent *caps* and the tendency when in use to '*pin*.'"

3. "That neither the extreme regularity of most machine work, nor the *uncertain* irregularity of much of the hand work, is most desirable in files for general use."

4. "That while most files should have teeth both irregularly spaced and of irregular heights, the degree should be strictly under control as in the increment-cut file."

## V.—HARDENING.

After cutting, the files are hardened, except those for use on wood or other comparatively soft substances, which are often left unhardened. To harden files they are first covered with paste and dried, to protect the teeth from the direct action of the fire. The paste is formed by passing the file through beer-grounds to make it sticky, then through a mixture of common salt with roasted and pulverized carbonaceous materials, which are considered to be the best adapted for the protection of the teeth against decarbonization and oxidation, while at the same time by their fusion upon the surface they indicate the proper heat to be given. This surface coating, being a poor conductor of heat, checks the sudden change of temperature when the file is first immersed in the tempering solution of cold water or brine, and diminishes the liability of the file to "check" or crack. The file is heated to an even red heat, or until the surface coating fuses, before being plunged in the cold bath. Hardening generally distorts the form of the file, to correct which it is withdrawn from the bath before entirely cold and placed in clamps to straighten it, or else is corrected by placing between a pair of iron bars and bending back by pressure upon the tang while cold water is poured upon the upper side to "set" the metal in the required position. Next "draw" or soften the tang by heating it in molten lead, which partially anneals it and obviates the danger of breaking off the tang when in use. The files are then thoroughly scrubbed and washed in lime-water to remove the scales of the salt mixture, after which they are dried, brushed, and oiled, when they are ready for use. The operation of hardening requires a good deal of skill and judgment in consequence of the diverse shapes of files, and, in many cases, of their unsymmetrical sections. Some files require to be immersed quickly, others slowly; some vertically, others obliquely, depending on the form of the file. The method of immersion adopted being that which has been found to give the most uniform

results and to preserve the straightness of the particular form of file. Despite the most scrupulous care in heating and immersing in the cold bath, files will often curve or "crook" in cooling. This defect is remedied to a great extent by forcing the file back to or beyond the straight line at the point of maximum curvature, and brushing it with cold water, or cold brine, on what was the *concave* side. This operation "sets" the file very nearly in the position to which it is strained by the dexterous hand of the workman. The straightening must be done before the file is thoroughly chilled, for no amount of pressure will correct the curvature after the metal becomes set.

Nearly every file-maker has his own peculiar ideas in regard to the composition of the paste he uses and the proportions of the ingredients in his hardening baths, and often endeavors to surround his proceedings with an air of mystery; but it is doubtful whether these carefully-guarded secrets are of much practical value. Good steel intelligently treated, proper attention given to temperature and specific gravity of the bath, which affect the degree of hardness and the straitness of the file, are all that are necessary to produce a good quality of work.

### VI.—Inspection.

The merest novice in the manufacture of any class of tools will at once understand the urgent necessity for frequent inspections of the work during the processes of fabrication. Files are no exception to this rule. They should be inspected at every stage of the manufacture, and defective ones rigidly rejected. The inspectors should be men of intelligence and skill, well paid, and entirely independent of the workmen. The maker should have foresight enough to support his inspectors in their decisions, if he expects the work to possess a high character for quality and excellence. Unwearied watchfulness and an honorable pride in his work are essential requisites for the establishment and retention of a high reputation. The wise manufacturer will *never* hazard a well-earned reputation by throwing an inferior quality of work upon the market.

### VII.—Testing.

A final examination of the files is made after hardening. The Nicholson File Company pursue the following method in the final inspection:

1. *Testing.*—The files are tried upon the hardened provers to ascertain if they are sharp and uniformly hard.
2. *Ringing.*—The files are next struck upon a block of metal, or "rung" as it is called, to find out if they are sound and free from fire-cracks.
3. *Inspecting.*—They are carefully examined to see that the teeth are perfect, and that no imperfections either in general shape or in the stock have been overlooked.

If found defective in any of these points they are discarded from the grade of first quality. The rejected ones have the brand or stamp ground out, and the best are selected and sold as second quality; the others are classed as "wasters" or scrap.

The files are now cleaned and oiled to prevent rusting, when they are ready for packing.

### VIII.—Packing.

The general custom has been to pack the files in paper packages, each package containing from one half to three dozen files.

A later method has been to put them up in paper boxes holding from one half to one dozen files each. Printed labels are placed on the end and top of each box. This arrangement is specially desirable for the smaller files, but for heavy files, on account of their weight, paper packages are better.

Foreign files are shipped to this country in casks weighing from 500 to 800 pounds. Domestic manufacturers ship in boxes containing rarely more than 30 dozen files, since the dealers often order in small lots.

## IX.—FILE-CUTTING MACHINES.

These machines are made to cut files automatically. The general design consists of a table upon which the file blank is secured, which table is fed beneath a chisel that receives the blows from a trip hammer placed above the table. Many attempts have been made to produce machines for file cutting, but thus far hand-cut files still maintain their sway.

### I.—*Chronology.*

A. D. 1699.—Duverger, a Parisian mechanic, presented a file-cutting machine to the French Academy. A description of it appeared in the Journal des Savants, 1702.

A. D. 1725.—Fardonet.

A. D. 1740.—Thiout described a machine in his Traité de l'Horologie: "In Thiout's machine the file was attached to a screw slide suspended at the end by pivots and covered with an anvil plate of tin. The slide works upon a stationary anvil and is worked by a feed-screw moved at intervals the distance of the pitch of a tooth by means of a pin-wheel. The chisel is held on a jointed arm, beneath which is a spring to raise it after each blow, the latter being given by a vibrating drop-hammer." (*Knight.*)

A. D. 1756–1758.—Brachal and Gamain.

A. D. 1800.—Raoul, a French mechanic, "made files by machinery, and obtained a report upon them from a committee of the *Lycée des Arts* in which it was stated that they were equal to the best English hand-made files."

A. D. 1812.—Morris B. Belknap, of Greenville, Mass., patented a file-cutting machine.

William T. James, "who is said to have worked at Union Village, patented another."

A. D. 1836.—Capt. John Ericsson, then in England, patented a file-cutting machine, which is described in Holzapffel's work on *Mechanical Manipulation,* where it is stated that one machine could do the work of ten men.

Ericsson's machine cut several files at the same time. It was claimed that it introduced means "by which, in cutting taper files, the hammer is less raised in cutting the ends of files than at the middle, so as to proportion the force of the blow to the width and depth of the cut at different parts of the file. Two machines were used for double-cut files, the bed of one inclined to the right and the other to the left to give the different horizontal inclinations proper to these teeth." For single-cut *floats,* round and half-round files, a strait bed was used. These machines delivered about 240 blows per minute, or about treble the rate for hand-cutting. Two beds were employed, so that the operator could be adjusting blanks upon one while those on the other were being cut.

A. D. 1843.—Robinson—Cammel.—Sir John Robinson, an ex-presi-

dent of the Royal Scottish Society of Arts, suggested "the making of curvilinear files by cutting flat strips of steel plate and then rolling them into shape and tempering them. Cammel's improvement was to make the plate thinner toward the edges so that it might bend equally and not too much in the middle, as it was apt to do when of an even thickness. He also suggested to make the teeth by a graver in an automatic machine." (*Knight.*)

A. D. 1847.—George Winslow, of Boston, invented an ingenious machine described in *Appleton's Dictionary of Mechanics.*

A. D. 1858.—Milton D. Whipple invented a machine with which an attempt was made in this year to manufacture files at Ballardvale, Mass. Extensive works were built and a large capital invested. The company failed in 1869. Some of the machinery is still (1876) in operation.

A. D. 1860.—In this year a description of Skilton's machine appears in "Ure's Dictionary," vol. ii, pp. 202–204.

M. Bernot, of Paris, invented a machine some time between 1847 and 1860, which was described in detail by Byrne. It was used with some success in France and Belgium, and was introduced into Great Britain and the United States in 1860 or a little later.

"In this machine the chisel is driven by a cam as the file blank moves along beneath it, and the difference in height of teeth, which is given by the hand process in passing from the end to the middle of the file, and the reverse is thus imitated. Considerable sums of money were expended in the effort to make this process a success in Birmingham, but in vain. A few of these machines are still (1876) in operation at Pawtucket, R. I."

A. D. 1866.—The Weed File Company commenced operations at South Boston, Mass., in this year, but failed after working two years.

A. D. 1865.—W. T. Nicholson, of Providence, R. I., invented a lot of machinery for cutting files, which has proved more successful than any heretofore invented. The Nicholson File Company, of Providence, R. I., was organized in the spring of 1865, with the inventor at the head. This company is still manufacturing files by machinery. These files are known as "increment-cut" files, being spaced irregularly so as to imitate the hand-cut files. For further particulars in regard to the Nicholson files, see under its appropriate heading.

The following machines are figured by Knight in his *Mechanical Dictionary*, but no dates are given:

1. *Rotherham and Holden's file-cutting machine.*—(Plate XXI, Fig. 2.)—Of this machine Knight says: The blanks are secured side by side on the upper surface of the bed, which is automatically fed after each stroke by the feed-screw; a separate chisel and hammer acts upon each blank; the chisels are supported by springs or arms with roller feet, which bear upon the blank; the chisels are thrown back after each cut to raise a burr.

2. *Card and Studley's file-cutter.*—(Plate XXI, Fig. 1.)—In regard to this machine the same author says: "The sliding head to which the shank of the blank is clamped is actuated by a feed-screw and half-nut, the latter being automatically raised to stop the feed motion at the proper time. The anvil has a hemispherical block, whose convex side rests in a socket of its support. The anvil and feed movement are supported on a turn-table, by whose adjustment the inclination of the teeth is determined. The chisel is supported upon a flexible rod which is connected to the hammer handle by a spiral spring. The hammer is attached to a rock-shaft which has an adjustable arm acted on by a cam on the main shaft."

In regard to cutting files by machinery, Professor Thurston says: "This problem has * * * taxed the patience and has employed the ingenuity of some of the ablest mechanics of all countries for many years. Very small clock and watchmakers' files have been made by machinery for years. But the difficulties met with in the attempt to make larger files have seemed almost insurmountable. Maigne, in his *Dictionaire des Inventions*, remarks: 'It has seemed impossible to obtain machinery having the delicacy of touch of the practical hand of the file-cutter, which varies its action, the position of the chisel, and the force and direction of each blow according to circumstances.' The problem to be solved embodies the following conditions: To make [the] direction and intensity of the blow such as to give a cut of precisely the desired depth and, on curved surfaces, spread; to draw back the chisel without injuring the edge just made; to avoid a rebound or chattering of the chisel; to move the blank with such irregularity as shall insure uniformity in the distribution of the teeth; and to combine all these movements with absolute precision as to time of succession, and with such speed as shall enable the machine to compete successfully with hand labor. The Bernot and Nicholson machines seem to have been the most successful yet invented."

## PART II.

### RASPS.

(Plates I, V, X, XI, and XII.)

#### *Definition.*

The rasp, like the file, is an abrading tool, but differs in that its surface is studded by protruding, isolated teeth, instead of chisel-cut teeth. The teeth of rasps are formed by a pointed tool called a *punch*. The point of this punch is generally of a triangular pyramidal form, whose triedral angles vary in size according to the effect required to be produced. The spaces between the teeth are, comparatively, wider than those for files. The apparently irregular intermingling of the teeth is such as will produce the smoothest surface for the number of teeth on the rasp.

#### *Classification.*

The classification of rasps is very similar to that of files. Rasps have different degrees of coarseness, and the cuts are usually classed as—

1. Coarse.
2. Bastard.
3. Second-cut.
4. Smooth.

The coarse-cut is that used by horse-shoers; the bastard by machinists, carriage-makers, and wheelwrights; while the second cut is applied to shoe-rasps, and the smooth to cabinet-makers, &c. The rows of teeth range obliquely from left to right, or from right to left, and sometimes in circular arcs. The planes of the cutting faces of the teeth are generally placed at right angles to the axis of the file; but occasionally they are made with a slight obliquity, alternately to the right and left, for the purpose of allowing the teeth to clear themselves more freely from particles of stock.

### *Description.*

*Flat wood-rasp.*—This rasp differs from the *flat file* only in the form of teeth. The sides are generally cut *rasp*, bastard, and the edges coarse, single-cut; used by wheelwrights and carriage manufacturers.

*Flat shoe-rasps.*—A rasp made from the *flat* sections. It has parallel edges, both *safe*, and slightly tapered sides. One-half of each side is *rasp, second-cut;* the other half, *bastard, double-cut,* used for filing bottoms of boots and shoes, almost entirely replaced now by the half-round shoe-rasps.

### *Half-round shoe-rasp.*

These rasps have parallel edges with sides slightly tapering from the middle to the point. Sections shown in Plate IX.

The ends are rounded, single-cut; the edges uncut or *safe;* the side commonly *half-file* and *half-rasp reversed.* The file quarters, bastard, double cut; the rasp quarters, second cut. Sometimes made ¼ and ¾ file. This rasp is the one in most general use at this time.

### *Oval shoe-rasp.*

Often called "French shoe-rasps," and is oval on both sides; edges parallel and safe; sides tapered to a thinner point than above rasp. It is punched half *smooth rasp* and half *second-cut rasp* reversed.

### *Horse-rasps.*

(Plate XII.)

These rasps are known as tanged or plain rasps, and their sections are shown in the plate cited. Both kinds of rasps are made with one side *cut coarse, double,* and the other *punched* coarse, *rasp.* The teeth of *tanged* rasps face towards the points; those of plain rasps face toward each end from the middle. The edges are either single cut or hopped. Some plain rasps have half of one side rasp and the other half file, the relative position of the halves being reversed on the opposite side; they are then known as "Plain rasp, ½ file reversed." In some cases they have one, and half of the opposite side either rasp or file; they are then called "Plain rasp, ¾ rasp," "Plain rasp, ¾ file," depending on the case.

For certain purposes the edges of one or more of the rasp quarters are beveled and are called "Beveled-edge rasps." The terms "¼ beveled" or "½ beveled" should be added to complete the description, as "Plain rasp, ¾ file, ½ beveled," or "Plain rasp, ½ file reversed, ¼ beveled."

The "¼ beveled" is most commonly required.

The tanged rasp has a handle and is in general use in New England shoeing shops, and is sometimes used in the Middle States. The plain rasp is in general use in the Western, Southern, and Middle States for shoeing horses and mules.

### *"Racer" horse-rasp.*

(Plate XII.)

This rasp is a patented article, made by the Nicholson File Company, of Providence, R. I. It is distinguished from the ordinary rasp by the

peculiar arrangement of the teeth. As will be seen from the plate, the faces of the alternate rows of teeth are inclined to the perpendicular to the axis at reversed angles instead of being parallel to that perpendicular as is customary. This gives a shearing cut. It is said that the teeth are more durable and less liable to break off in use, and that they do not clog, since instead of the abraded material being packed in the depression in front of the tooth the action of the workman tends to press the refuse outward and make the rasp clean itself. Each tooth is made with a double blow. These rasps are made both tanged and plain.

*Half-round wood rasp.*

(Plates II, V, and IX.)

Similar in shape to the half-round file; length generally 10, 12, and 14 inches. It has bastard-cut punched teeth on both sides. Adapted for wood-work, but is used by plumbers and marble-workers.

*Cabinet rasp.*

(Plates II, V, and IX.)

Resembles the cabinet file except in cut. Length from 6 to 14 inches—8, 10, and 12 inches most common; cut, punched, smooth, sometimes second-cut. These rasps are used by wood-workers generally, on furniture, saddle-trees, lasts, gun-stocks, patterns, and wooden models.

*Jig-rasp.*

(Plate XII.)

This is a combined file and rasp, cut on the sides; one side is half rasp, and the other half *coarse* single-cut. On the opposite side both halves are *fine*, *second-cut*, single. This tool is used by fishermen for shaping the lead weights or sinkers attached to their nets.

*Rasp-cutting machine.*

This resembles the file cutting machine (which see) in the striking and feed-motion parts. It differs in the devices by which it is adapted to cutting rasps instead of files. To this end the chisel stock is pivoted to the rock-shaft, so that the chisel may be vibrated not only in a vertical plane, but also in a horizontal plane, thus cutting teeth in curved lines across the blank. The forward feed-motion is intermittent, taking place only after the completion of one row of teeth, and before the commencement of another.

*Stub files.*

(Plate XIV.)

These are short files, about 2 inches in length, of various cut and cross-section, and are designed to be used for finishing cavities, depressions, &c., where ordinary files cannot be used. The holder is attached to the files by screwing in the handle, which action spreads the jaws

apart and engages their points in the recesses in the backs of the file-stubs.

*Rifflers.*

(Plate XV.)

Rifflers are usually curved at both ends, the middle portion being used for a handle. Nicholson prepares his rifflers, as shown in Plate XV, with wooden handles, by which they are more readily controlled. These instruments are used by wood carvers, engravers, pattern-makers, stone and marble cutters.

*Scrapers.*

(Plate XVI.)

These are tools used by machinists to bring surfaces of machinery and gauges to the requisite degree of nicety and finish. They are employed to remove very small irregularities of surface. They are very hard and are ground to the proper shape. Nicholson's "Scraper Kit No. 1" is shown in Plate XVI.

*File-holders.*

(Plate XVII.)

These are devices to enable the filer to hold his file firmly when filing surfaces. They also enable him to give more or less convexity to the working face of his file, and thus produce greater nicety of finish by only filing the place where needed. Several patterns of these holders have been produced, but those of the Nicholson File Company are the most convenient and useful. The company makes two classes, *vise* and *surface* file-holders, numbered as follows:

*Vise file-holders.*

No. 1, for holding files 5 and 6 inches long.
No. 2, for holding files 8 and 10 inches long.
No. 3, for holding files 12 and 14 inches long.

*Surface file-holders.*

No. 4, for holding files 12, 13, and 14 inches long.
No. 5, for holding files 14, 15, and 16 inches long.

*File-cleaners.*

(Plate XVII.)

These are the file-card, file-brush, and scorer, and are used for freeing the teeth of the files when clogged by particles of material. The card is made of wire "card clothing," and the scorer of soft wrought iron. The brush is used in conjunction with the card for cleaning fine files. The scorer is used for removing the pins or "cat teeth" which obstruct the teeth of the file and score or groove the work.

## PART III.

### THE ART OF FILING.

To the uninitiated the operation of filing seems to be a very simple matter, and one that can easily be attained by any person. On the contrary, the art of *filing well* is one which requires a great deal of skill and long-continued practice, as well as thought and judgment. It is true that in many shops there can be found filers who possess neither skill nor judgment, but who, from long practice on some special classes of work, have become known as filers. Such men, however, are not, and do not deserve to be, called "good filers." It is also true that this same class of inferior workmen generally claim to be, and doubtless believe that they are, excellent filers. A rigid system of inspection and a persistency in pointing out the multitudinous defects of their "finished work" (so called) would result in instilling into their minds a belief that they were being persecuted, and that the foreman or superintendent was "down on them, and was seeking opportunity to find fault with their work." Very ignorant filers, as well as other classes of mechanics, artisans, and even professional men, are often as bigoted and self-conceited as they are unskillful and opinionated. With many of them it is an almost hopeless task to attempt to eradicate slovenliness in their manner of filing, especially after years of practice in such methods. Examples are numerous where men who have been filing (?) for years do not even "know how to hold their files." Gun-makers, master mechanics, and superintendents of manufacturing establishments where a great deal of filng is required, all know the difficulty of obtaining good filers. The supply is not equal to the demand, and the inequality increases yearly, and has done so since the practical abolition of the apprentice system in this country. The advent of planers, shaping-machines, trimming machines, shaving machines, and milling-machines has greatly diminished the amount of filing formerly required in machine and gun shops; and filing, in its widest sense, is apparently about to be remanded to the category of the "lost arts." Boys and young men go to work on a machine, and find that in a few weeks or months they can earn fair pay without any previous study or apprenticeship; consequently it is not strange that they are loth to spend several years of apprenticeship in endeavoring to learn a trade which, when obtained, will bring little or no advance of remuneration. Again, proprietors of machine-shops are in such haste to get rich that they do not wish to employ any but skilled workmen, hence they refuse to be "bothered" with teaching boys who will probably leave their shops as soon as they have learned their trade. The old filers who have learned the trade regularly by a toilsome apprenticeship are gradually dying off, and no new brood is being educated to supply their places. Hence the complaint is constantly heard that we cannot find enough good filers. How this evil is to be remedied is not within the province of this paper, and the writers merely wish to call attention to the fact. There are few mechanical operations that present greater difficulties than that of filing well. If a planer be used, the work is firmly fastened to the movable bed-plate, which has a motion of translation along fixed guide-rails, and passes under a tool attached to a tool-post with an automatic, transverse feed-motion. If a shaper be employed, the work is keyed to the immovable bed and the tool has a motion of translation and rotation, the former governed by fixed guides and the latter by a screw. In neither of the cases above cited does the accuracy of the work depend upon the workman's skill after the machine

has been set and put in motion. But in filing, the "guiding principle" of the machine is absent, and the accuracy of the work depends upon the constant care, skill, and judgment of the man. To produce a "*true flat surface*" upon narrow work is an excellent test in filing. One would naturally suppose that a file the points of whose teeth lie in the surface of a single plane is all that is required to do the work. Even if the *side* of the file was a *perfectly* plane surface—which it never is—it would be necessary to move it in parallel straight lines across the work to produce the required effect. Supposing this operation possible, the pressure applied at the ends of the file, as is usual, would spring the file and produce a concavity on its under surface, which in turn would naturally round the work. To obviate this defect the file should have its sides slightly convex. The greater the convexity of the file the fewer teeth that come in contact with the surface and the better will the file cut or bite, provided the pressure remains constant. The convexity is sometimes given by slightly curving or tapering the sides from about the middle to the point. A better way, perhaps, is to have the gradual curvature extend from the heel to the point. The advantages of the convexity are plainly seen when the attempt is made to produce an approximately true plane surface. The straight edge or surface plate will show the points on the surface, which are a little higher than the rest; and without a file with convexity it is impossible to touch the exact spot desired and no other.

*Putting handles on files.*—Before using a file the workman should see that the handle is driven well up to the shoulder of the tang. Care must be taken not to split the handle. If the hole for the tang be too small it can be easily enlarged by heating the tang of an old or worn-out file and burning out the hole. This method can also be used for centering a hole that is bored eccentrically. The handle should always fit closely to prevent accidents arising from the pulling off of the handle, when the workman might injure his hand by striking it against the tang. It also lessens the danger of breaking off the tang, which might occur were the handle only half-way on the tang. File-holders are also useful in preventing accidents as well as for providing a method of increasing more or less the curvature or "belly" of the file. Holders are especially desirable when using stub files.

*Position of filing vise.*—Nearly every workman has his own ideas in regard to the height of his vise-jaws above the floor upon which he stands. The position of the vise depends of course upon the kind of work upon which he is engaged. The general custom is to place the jaws of the vise at about the height of the elbow from the floor for general work; this will be in the neighborhood of 42 inches. In filing on small or delicate work, where the movements are confined to those of the hands and arms alone, the vise may be placed at a greater distance from the floor, in order to bring the work nearer to the eyes of the filer and relieve him from too much bending over. Heavy work, such as surface filing, requiring considerable pressure to make the file bite, and greater rigidity of the arms, renders it necessary to place the vise lower, so that the weight of the body can assist in the forward thrust of the file. In this case the feet of the operator being farther apart than usual his stature is slightly diminished.

*Grasping the file.*—This manipulation cannot be better described than by reproducing the directions given on this point by Mr. Nicholson in his "*Treatise on Files*," which are as follows: "In using the larger files, intended to be operated by both hands, the handle should be grasped in such a manner that its end will fit into and bring up against the fleshy

part of the palm, below the joint of the little finger, with the thumb lying along the *top* of the handle in the direction of its length, the ends of the fingers pointing upward, or nearly in the direction of the operator's face.

"The point of the file should be grasped by the thumb and first two fingers, the hand being so held as will bring the thumb, as its ball presses upon the top of the file, in a line with the handle, when heavy strokes are required. When a light stroke is wanted and the pressure demanded becomes less, the thumb and fingers may change their direction until the thumb lies at a right angle, or nearly so, with the length of the file; the positions change more or less, as may be needed to increase the downward pressure.

"In holding the file with one hand, as is often necessary in filing light work, pins, &c., the handle should be grasped as already described, with the exception that the hand should be turned a quarter turn, bringing the forefinger on the top and lying along the handle nearly in the direction of its length. In this position the freest action of the hand and wrist may be had upon light work.

"Amateurs will find that by following these directions the movements of the file will be simplified and made somewhat easier than if grasped at random and without consideration."

USES AND EFFECTS OF FILES.

Files are used upon surfaces of all kinds. Rasps are used upon those materials whose particles possess less resisting power, and are chiefly employed for rapid work. They are more used by workers in wood, soft metals and leather, than are files.

The general effects of rubbing a file or rasp upon the surface of metal, wood, ivory, leather, or other material is to smooth it and change its form and dimensions. The abrasive effect consists in cutting from the surface small shavings or particles and in gradually reducing the mass. Therefore, files are only used for shaping and smoothing small pieces, or in finishing surfaces that are already of approximate figure. The file usually follows the work of the lathe, the planer, the milling machine, or the profiling machine. In the natural motion of filing the tendency is to impart to the file a somewhat circular motion, the articulation or joints of the arms and hands acting as centers of motion. It would seem that this kind of motion with a convex file should produce concavities in the work, whereas the real effect is to give a slight convexity to the work, due to the rocking motion caused by the work acting as a kind of fulcrum, except where the file is handled by a skillful manipulator.

Every filer should aim to have his file, during the stroke, depart from a strait line just enough to bring it into contact with the desired portion of the work. The filing of round or curved surfaces requires that the strokes should be so blended as to produce the best effect. This class of filing depends a good deal upon the experience and eye of the workman, but is not so difficult as absolutely *flat* filing.

In *draw-filing* the files are grasped at each end by the hands and moved transversely across the work. The exact angle at which the file is held is governed by the angle of the last or *up cut* of the files, and must be sufficient to produce a shaving cut. As files are intended to cut during a forward stroke, it is evident that they will not cut to advantage in draw-filing; hence the operation of draw-filing is only resorted to when but little stock is to be removed. This operation is

useful in finishing surfaces, in fitting lathe-turned shafting to fit couplings, and in laying the strokes of a preceding filing by obliterating the scratches and substituting finer ones at right angles to them. The pressure upon the file should be relieved or entirely removed during the back stroke in both forward and draw-filing, in order to economize the wear upon the teeth. For new files, attention should always be given to the kind of material upon which first used. To secure the greatest economy, new files should be used in finishing the larger surfaces of cast iron, bronze, or brass, which require a keen-cutting tooth, or upon narrow surfaces of wrought iron or steel. A very light pressure upon the work should be used until the needle-like points of the teeth are worn off, else the teeth are liable to be broken off and the file rendered worthless. A few careless strokes when first used are apt to destroy greatly the efficiency of the file. A worn file should be used in the first attack upon the rough surface of iron work covered with "scale" to pave the way for the employment of a new file. The latter should never be used upon the gritty skin of castings, nor upon a weld where borax or any vitreous flux has been employed. These surfaces may not injure a partially worn file, while they would ruin a new one. The filer should always see that the shape and cut of his file is adapted to the work in hand. He must not expect a brass or lead float to work well upon a surface of steel, nor a dead-smooth file to cut rapidly the surface of a brass casting. In filing steel, the best results are generally obtained by using files whose grade is not coarser than "second cut." Finer files are required where great delicacy of finish is necessary.

In preparing the work for the file great care should be taken to remove the hard, chilled outer skin or "scale" and sand by "pickling" before sending it to the filer.

*The use of oil on files.*—All files are oiled, to prevent rusting, when they leave the manufacturer's hands. In many cases the oil does no harm, but for use upon large cast-iron surfaces the oil should be removed or the teeth will not penetrate the surface, and it will "glaze." This action not only hardens or burnishes the surface, but dulls or breaks off the points of the teeth. Upon fibrous metals oiled files may be used, and workmen often fill the teeth with oil and chalk. Oil is useful on fine files for finishing purposes, as it keeps the teeth from penetrating too much, and tends to prevent "pinning" and its consequent scratching.

*Cleaning and care of files.*—Files should be frequently cleaned to remove the dust and filings from the teeth. These obstructions keep the teeth from penetrating the work and give the file the appearance of being worn. When the teeth are clogged with wood, horn, or bone, the tendency to rust is aggravated. The file should not only be cleaned at intervals during the work, but before being laid aside. Fine files are cleaned by rubbing the palm of the hand over them, by drawing them across the workman's apron, by striking their edges (lightly) on the bench or vise, or by using a strip of file-card or a brush. Oil is removed from the teeth of new files by rubbing charcoal or chalk over the teeth and then thoroughly brushing them. When the teeth become wedged or filled with wood or other soft substances, holding them in boiling water for a few minutes will swell the wood so that it may be easily removed by the file-card. If quickly performed the remaining heat will evaporate the moisture and prevent rusting. Careless mechanics destroy their files by throwing them together, coarse and fine, into a tray or drawer filled with tools, pieces of iron and steel, and throwing cold chisels, hammers, jigs, etc., upon them. It is easy to see how this treat-

ment will break the teeth and destroy the efficiency of a file. A careful filer will always have a rack of some kind upon which his files are systematically arranged.

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## PART IV.

### MANUFACTURE OF FILES AT THE NATIONAL ARMORY, SPRINGFIELD, MASS.

The Ordnance Department employs one skilled file-cutter at the National Armory, who is kept constantly employed in recutting worn-out files and in making special files for certain classes of work required in the fabrication of small-arms. All the rotary files used in the establishment are also cut here. Since the introduction of "gun steel" or Bessemer steel as the material for many of the components of arms, a good many files are used which are "new cut" or "skew cut." This "new" or "skew cut" is one in which the first course or *over cut* is a light cut with small horizontal obliquity, while the second course or *up cut* is coarser, with great horizontal obliquity. This method of cutting is excellent for a finishing file, and is very popular among armorers on account of the ease of manipulation and freedom from clogging, as well as the smoothness of the surface produced. But, unless the quality of the milling be excellent, these files do not produce good results except with a great expenditure of time, a thing piece-workmen especially desire to avoid. The operations at this armory are as follows:

#### 1. *Forging.*

For new files the blanks are generally forged from bar steel whose cross-section is a close approximation to that of the intended file. Thus, blanks for round files are forged from round bars; for half-round files from half-round bars, &c. The steel used for files is specially selected and must possess great uniformity of density and be highly carbonized.

#### 2. *Annealing.*

The file blanks are hardened more or less by the process of forging and must be softened by annealing. For this process the blanks (or worn-out files to be recut) are closely packed with fine charcoal in an iron retort, and the latter rendered air-tight by luting down the lid with fire clay. The retort when packed is placed in a furnace and slowly heated until the whole is raised to a cherry-red heat, and then removed from the furnace and allowed to cool slowly. After cooling the blanks or old files are straightened by the aid of a hammer and anvil.

#### 3. *Grinding.*

The file blank is first transversely or "cross-ground" in front or on top of a grindstone, and then is ground in the direction of its length. The workman must be careful to preserve the shape of the blanks during this operation. After grinding, the blanks or old files are inserted in air-slacked lime to absorb the moisture and prevent rusting.

### 4. *Draw-filing.*

(Plate XXVI.)

This operation is generally known among file cutters as "stripping." It is employed to smooth and level the surfaces of the blank and prepare it for the operations of the file-cutter.

For this purpose a file is used.

### 5. *Cutting.*

(Plates XXIII, XXIV, XXV, XXVI, and XXVII.)

This is done by placing the blank upon a block or anvil of cast or wrought iron (Plate XXVI, Fig. 1) imbedded in a block of stone. A thin sheet of lead or a block of tin is placed upon the iron tablet or anvil to preserve the file teeth from injury during the process of cutting. The different grades of teeth are produced by using hammers of different weights and delivering blows of greater or less intensity, in conjunction with chisels of greater or less weight, having edges with angles of the proper amplitude. The obliquity of the courses of cuts or indentations is governed by the angle at which the chisel is held with respect to the axis of the file, and the character of the teeth by the inclination given to the chisel, coupled with the intensity of the blow struck by the hammer.

### 6. *Preparation for hardening.*

Before hardening, the files are treated with a mixture of salt and carbonaceous materials to protect the teeth from decarbonization and oxidation. The kinds and proportion of the ingredients are exhibited in the following table:

| Kind. | Proportion. |
|---|---|
| Pulverized charcoal made from leather clippings | 1 pound. |
| Fine family flour | 1¼ pounds. |
| Fine table salt | 2 pounds. |

The charcoal made from burnt leather is triturated until fine enough to pass through the meshes of a No. 45 sieve.

The three ingredients are thoroughly mixed and incorporated while in a dry state, and water is then added slowly to prevent lumps until the paste formed has the consistency of ordinary varnish; when ready the paste is applied to the files with a brush, care being taken to have the teeth well filled with the mixture. The surplus paste is then wiped from the files by the brush, and the files placed on end before a slow fire to dry. If dried too quickly the paste will crack or blister; if not dried enough the remaining moisture will be transformed into steam when dipped into the heated lead-bath and cause an ebullition or sputtering of the lead, throwing out minute globules of the latter which may endanger the eyes of the operator. The fusion of the paste upon the surface of the file indicates the proper heat at which to harden the file. The presence of this partially non-conducting coating of paste also checks the first sudden change of temperature when immersed in the lead-bath and diminishes the liability of the files to "check" or crack.

Many files, especially those with unsymmetrical sections, are apt to be more or less curved by hardening. This defect is overcome in a great degree by bending or distorting the file in the opposite direction while yet soft, so that it may be of the required form when hardened. Expe-

rience will guide the operator in the amount of bending necessary with the different brands of steel and the various forms of cross-sections.

### 7. *Hardening.*

When dry the paste-covered files are seized by the tangs with a pair of tongs, one at a time, and slowly immersed in a vertical direction, point first, in a pot of heated lead. The slow immersion enables the hot lead to drive off any remaining moisture without danger to the workman. The surface of the lead-bath is covered with wood charcoal to prevent oxidation and preserve a constant temperature. When the proper heat is reached, generally shown by the fusing of the saline mixture upon the surface of the file, the latter is withdrawn from the heated lead and plunged into a cold saturated solution of common salt. The rapidity and method of immersion depend upon the kind and shape of the file. Flat, taper, square, triangular, and round files are immersed vertically. Knife edge files have the thick edge or back first exposed to the cold brine. Half-round and cant files have the flat side down in immersion. The latter classes are slightly distorted so as to present a slight concavity on the flat side before being plunged into the hardening liquid.

### 8. *Straitening.*

While the files are still warm they are removed from the cold salt-water bath and examined by the eye to see whether they are curved or not. If curved the workman seizes the tang and places the point of the file under the farther one of two parallel bars of iron (Plate XXVI, Fig. 4), and resting the convex side upon the other parallel bar bears down upon the tang with his left hand, springing the file in the opposite direction, while with his right hand he applies cold water with a brush at the point where the concavity existed. This treatment sets the fibers of the iron on the upper side in their new position while those on the under side still retain a portion of their heat. During this manipulation the temperer frequently glances his eye along the edge of the file to observe the effect of his application of cold water and pressure. After straightening, the burnt paste is removed by means of a stiff brush, using fine sand and water. This operation is technically called scouring; after which the file is first rinsed in clean fresh water and then in lime-water with the lime well stirred up. The files are now placed on end to dry. They will be covered with a slight coating of lime, which will prevent rusting. The tang and shoulder is then tempered or "drawn" by immersing in a hot lead bath to prevent breaking off in use. When thoroughly dry the lime is removed by brushing; the files examined to see if they are straight, and then oiled with sperm-oil and packed away for future use.

Should any of the files prove to be slightly bent they are placed with the convex side in contact with a block of metal of proper form and size, heated to a black heat with the point beneath an adjustable screw (Plate XXVII, Fig. 5), and pressure applied in a downward direction upon the tang, while sperm-oil is applied upon the concave side until the metal is set in the new position. When straight the files are placed in sperm-oil to cool.

## FILE CUTTER'S TOOLS.

### (Plates XXIII, XXIV, and XXV.)

The chisels, punches, and hammers used by the file-cutter at the National Armory are shown in the plates above mentioned, drawn to

scale. The weights of the several chisels and hammers are given in the tables below. The numbers correspond to those in the drawings.

---

1. *Weights of chisels and punches.*

FILE CHISELS.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. 7½ oz. | 3. 6 oz. | 5. 3½ oz. | 7. 2½ oz. | 9. 1½ oz. | 11. 1½ oz. | 13. ½ oz. |
| 2. 6½ oz. | 4. 4½ oz. | 6. 3 oz. | 8. 2 oz. | 10. 1½ oz. | 12. 1½ oz. | |

HORSE RASPS.

| | | | |
|---|---|---|---|
| 14. Chisel | 8½ oz. | 16. Punch | 2½ oz. |
| 15. Punch | 5½ oz. | 17. Punch | 1½ oz. |

MISCELLANEOUS.

| | | | |
|---|---|---|---|
| 18. End chisel for rotary files | 1½ oz. | 22. Convex chisel | 4 oz. |
| 19. " " " " " | 1½ oz. | 23. Plier | 1 oz. |
| 20. " " " " " | 1 oz. | 24. Oblique | 3 oz. |
| 21. Concave chisel | 2½ oz. | 25. Oblique | 2 oz. |

2. *Weights of file-cutter's hammers.*

| | | | | | |
|---|---|---|---|---|---|
| 1. 6 lbs. 8½ oz. | 3. 4 lbs. 3 oz. | 5. 3 lbs. | 7. 1 lb. 13 oz. | 9. 13 oz. | 11. 4 oz. |
| 2. 5 lbs. 11½ oz. | 4. 3 lbs. 9½ oz. | 6. 2 lbs. 6 oz. | 8. 1 lb. 4 oz. | 10. 7 oz. | |

FILES USED AT THE NATIONAL ARMORY, WITH THE SEVERAL OPERATIONS AND COMPONENTS TO WHICH THEY APPLY.

1.—MACHINE SHOP.

FILES USED.

| Kind. | Cut. | Length. |
|---|---|---|
| | | *Inches.* |
| Cant | Bastard | 5 to 6 |
| Cant | Second cut | 3 to 7 |
| Cant | Smooth | 3 to 7 |
| Cant | Smooth, skew | 3 to 6 |
| Cant | Dead-smooth, Stub's | 3 to 6 |
| Cant | Dead-smooth, Stub's | 2 |
| Cross | Bastard | 6 to 8 |
| Cross | Second cut | 6 to 8 |
| Cross | Smooth | 3 to 8 |
| Cross | Dead-smooth | 3 to 5 |
| Equaling | Bastard | 4 to 8 |
| Equaling | Smooth, Stub's | 2 to 3 |
| Flat | Bastard | 6 to 12 |
| Flat | Second cut | 4 to 8 |
| Flat | Smooth | 3 to 8 |
| Flat | Skew | 6 to 12 |
| Float | Second cut | 5 to 12 |
| Float | Smooth | 5 to 12 |
| Hand | Bastard | 6 to 12 |
| Hand | Second cut | 4 to 12 |
| Hand | Smooth | 4 to 12 |
| Hand | Dead-smooth | 2 to 10 |
| Hand | Smooth, skew | 6 to 12 |
| Hand | Grobet, No. 6 | 3 to 5½ |
| Horse-rasp | Rasp and bastard | 12 |
| Knife | Bastard | 4 to 8 |
| Knife | Second cut | 3 to 7 |
| Knife | Smooth | 3 to 7 |
| Knife | Dead-smooth, Stub's | 3 to 7 |
| Knife | Dead-smooth, Grobet, No. 6 | 3 to 5 |
| Oval | Smooth | 10 |
| Oval | Second cut | 9 |
| Pillar | Bastard | 4 to 12 |
| Pillar | Second cut | 4 to 10 |
| Pillar | Smooth | 2 to 6 |
| Pillar | Smooth, skew | 4 to 12 |
| Pillar | No. 6, Grobet | 2 to 6 |
| Pillar, narrow | No. 6, Grobet | 4 to 5 |

*Files used at the National Armory, &c.*—Continued.

| Kind. | Cut. | Length. |
|---|---|---|
| | | *Inches.* |
| Round | Bastard | 2 to 21 |
| Round | Second cut | 2 to 10 |
| Round | Smooth | 2 to 10 |
| Round | Smooth, Stub's | 2 to 6 |
| Round | Smooth, Grobet, No. 6 | 3 to 6 |
| Round-joint | Stub's | 3 to 8 |
| Half-round | Bastard | 3 to 12 |
| Half-round, high back | Bastard | 8 to 12 |
| Half-round | Smooth | 3 to 8 |
| Half-round | Dead-smooth, Stub's | 3 to 7 |
| Half-round | Dead-smooth, Grobet, No. 6 | 3 to 6 |
| Square | Bastard | 3 to 12 |
| Square | Second cut | 3 to 12 |
| Square | Smooth | 2 to 8 |
| Square | Dead-smooth | 2 to 6 |
| Square | Dead-smooth, Grobet, No. 6 | 2 to 5 |
| Screw-head | Dead-smooth, Stub's | 2 to 3 |
| Three-square | Bastard | 6 to 10 |
| Three-square | Second cut | 2 to 6 |
| Three-square | Second cut, single | 2 to 9 |
| Three-square | Smooth | 2 to 6 |
| Three-square | Smooth, single | 2 to 6 |
| Three-square | Dead-smooth, Stub's | 2 to 5 |
| Three-square | Dead-smooth, Grobet, No. 6 | 2 to 5 |

## 2.—FORGING SHOP.

### FILES USED.

| Component. | Operation. | Kind. | Cut. | Length. |
|---|---|---|---|---|
| | | | | *Inches.* |
| Barrel | Muzzle, first filing | Mill-saw | Second cut | 14 |
| | Muzzle, first filing | Float | Smooth | 12 |
| | Front sight, stud filing | Flat | Smooth | 12 |
| | Muzzle, second filing | Float | Smooth | 12 |
| | Front sight, stud jigging | Pillar | Second cut | 8 |
| | Muzzle, finishing | Flat | Dead-smooth | 12 |
| | Muzzle, finishing | Pillar | Second cut | 8 |
| Ramrod | Slot filing | Hand | Second cut (cut on edge) | 10 |
| | Slot filing | Hand | Second cut (round edge) | 6 |
| | Slot filing | Flat | Second cut | 6 |
| Bayonet | Socket burring | Round | Bastard | 12 |
| | Slot filing | Flat | Second cut | 12 |
| | Slot filing | Flat | Smooth | 10 |
| | Slot filing | Pillar | Smooth | 10 |
| | Slot filing | Round | Second cut | 8 |

*Special files made at National Armory for forging shop.*

Twelve-inch hand, $1\frac{1}{8}$ inches wide, dead-smooth, single cut.
Twelve-inch hand, $1\frac{1}{4}$ inches wide, skew-cut, smooth.
Nine-inch pillar, $\frac{3}{16}$-inch wide, skew-cut, smooth.
Five-and-a-half-inch equaling, round edges, skew-cut, second cut, .38-inch wide, .075 thick before cutting, for rod-head slot.

## 3.—MILLING SHOP.

### FILES USED.

| Component. | Operation. | Kind. | Cut. | Length. |
|---|---|---|---|---|
| | | | | *Inches.* |
| Barrel | Fourth turning | Hand | Second-cut float | 12 |
| | Fifth turning | Hand | Second-cut float | 12 |
| | Sixth turning | Hand | Smooth | 6 |
| | First drilling | Hand | Smooth | 6 |
| | Seventh turning | Hand | Smooth | 8 |
| | Countersinking | Hand | Smooth | 8 |
| | Profiling | Hand | Smooth | 8 |
| | Tapping | Hand | Smooth | 6 |
| | Filing | Hand | Bastard | 8 |
| | Filing | Hand | Smooth | 6 |
| | Filing | Hand | Dead-smooth | 6 |
| | Filing | Hand | Dead-smooth | 4 |

*Files used at the National Armory, &c.*—Continued.

| Component. | Operation. | Kind. | Cut. | Length. |
|---|---|---|---|---|
| | | | | *Inches.* |
| Bridle | First milling | Hand | Smooth | 6 |
| Breech screw | Second milling | Hand | Smooth | 8 |
| | Third milling | Hand | Smooth | 8 |
| | Third milling | Three-square | Smooth | 6 |
| | Second filing | Hand | Smooth | 10 |
| | Second filing | Three-square | Smooth | 6 |
| Breech block cap | Drilling | Hand | Second cut | 10 |
| Breech block | First milling | Hand | Bastard | 12 |
| | Second milling | Hand | Second cut | 12 |
| | Third milling | Hand | Second cut | 12 |
| | Fourth milling | Hand | Second cut | 10 |
| | Fifth milling | Hand | Second cut | 10 |
| | Seventh milling | Hand | Second cut | 10 |
| | Ninth milling | Hand | Second cut | 10 |
| | Tenth milling | Hand | Second cut | 10 |
| | Fifth profiling | Hand | Second cut | 10 |
| Butt plates | First filing | Half-round | Bastard | 12 |
| | First filing | Half-round | Second cut | 12 |
| | First filing | Round | Second cut | 10 |
| | Second filing | Half-round | Bastard | 12 |
| | Second filing | Half-round | Second cut | 12 |
| | Second filing | Half-round | Second cut | 10 |
| Cam latch | First filing | Hand | Smooth | 10 |
| | Ninth milling | Hand | Smooth | 8 |
| | Burring | Hand | Smooth | 6 |
| Extractor | Second milling | Hand | Bastard | 8 |
| | Third milling | Hand | Second cut | 10 |
| | Third milling | Hand | Smooth | 7 |
| | Fourth milling | Hand | Bastard | 8 |
| | Profiling | Hand | Second cut | 10 |
| | Profiling | Hand | Smooth | 7 |
| Firing pin | Fifth milling | Half-round | Smooth | 6 |
| | First profiling | Hand | Smooth | 8 |
| | Sixth milling | Hand | Smooth | 6 |
| Front sight | Filing | Flat | Smooth | 6 |
| Hinge pin | First milling | Hand | Smooth | 12 |
| | First milling | Hand | Smooth | 6 |
| Hammer | Drilling | Flat | Bastard | 12 |
| | Third milling | Half-round | Second cut | 10 |
| | First profiling | Flat | Smooth | 10 |
| | First profiling | Half-round | Smooth | 8 |
| Lock plate | First milling | Flat | Bastard | 12 |
| | Fourth profiling | Half-round | Bastard | 8 |
| Receiver | First milling | Flat | Bastard | 12 |
| | Third milling | Flat | Bastard | 12 |
| | Fourth milling | Hand | Bastard | 12 |
| | Fifth milling | Flat | Second cut | 10 |
| | Fifth milling | Flat | Second cut | 12 |
| | Third drilling | Flat | Second cut | 10 |
| | Sixth milling | Flat | Second cut | 8 |
| | Seventh milling | Flat | Second cut | 8 |
| | Second profiling | Flat | Second cut | 8 |
| | First filing | Flat | Smooth | 8 |
| Ramrod stop | Third milling | Hand | Smooth | 8 |
| | Fourth milling | Hand | Smooth | 6 |
| | Fourth milling | Half-round | Smooth | 6 |
| Rear-sight base spring | Burring | Hand | Smooth | 10 |
| Rear-sight bases | First milling | Flat | Smooth | 12 |
| | Second milling | Flat | Smooth | 12 |
| | Third milling | Flat | Smooth | 12 |
| | Fourth milling | Hand | Smooth | 8 |
| | Burring | Hand | Smooth | 12 |
| | Burring | Hand | Smooth | 8 |
| | Seventh milling | Flat | Smooth | 12 |
| Rear-sight leaves | First milling | Flat | Second cut | 10 |
| | Second milling | Flat | Second cut | 10 |
| | Sixth milling and burring | Flat | Smooth | 8 |
| Rear-sight buckhorn plates. | First milling | Flat | Bastard | 12 |
| | Second milling | Hand | Second cut | 6 |
| | Third milling | Hand | Smooth | 8 |
| | Third milling | Half-round | Smooth | 5 |
| | Drilling and reaming | Half-round | Smooth | 7 |
| | Drilling and reaming | Flat | Smooth | 7 |
| | Fifth milling | Hand | Smooth | 9 |
| | Fifth milling | Flat | Second cut | 9 |
| | Fifth milling | Half-round | Second cut | 5 |
| | Fifth milling | Half-round | Smooth | 5 |
| Rear-sight slide plates | First milling | Hand | Smooth | 10 |
| | Second milling | Hand | Smooth | 7 |
| | Second milling | Hand | Smooth | 4 |
| | Counterboring | Hand | Smooth | 6 |
| | Tapping | Hand | Smooth | 6 |

*Files used at the National Armory, &c.*—Continued.

| Component. | Operation. | Kind. | Cut. | Length. |
|---|---|---|---|---|
| | | | | *Inches.* |
| Rear-sight slide blocks | Second milling and burring. | Hand | Smooth | 12 |
| Sears | Third milling | Hand | Smooth | 10 |
| Side screw washers | Filing | Flat | Smooth | 10 |
| Tumbler | Fifth milling | Hand | Smooth | 8 |
| | Squaring | Hand | Smooth | 8 |
| | Crowning | Hand | Smooth | 10 |
| Thumb pieces | Second milling | Flat | Second cut | 12 |
| | Second profiling | Hand | Smooth | 10 |
| | Second profiling | Hand | Smooth | 8 |
| | Third milling | Square | Smooth | 6 |
| Butt plate covers, carbine. | First profiling | Hand | Smooth | 8 |
| | Second profiling | Hand | Smooth | 8 |
| | Drilling | Hand | Smooth | 8 |
| | Fifth milling | Hand | Smooth | 6 |
| | Sixth milling | Hand | Smooth | 8 |
| Screw-driver blades, small | Burring | Hand | Smooth | 8 |
| Screw-driver blades, large | First milling | Hand | Smooth | 12 |
| | First milling | Hand | Smooth | 6 |
| | First drilling | Hand | Smooth | 8 |
| | Second milling | Hand | Smooth | 6 |
| Headless shell extractors | First milling | Flat | Smooth | 12 |
| | Heading | Flat | Smooth | 10 |
| | Burring | Hand | Smooth | 10 |
| | Inspection | Flat | Bastard | 12 |
| | Inspection | Flat | Second cut | 12 |
| | Inspection | Flat | Smooth | 10 |
| | Inspection | Flat | Smooth | 6 |
| | Inspection | Flat | Dead-smooth | 6 |
| | Inspection | Half-round | Dead-smooth | 6 |
| | Inspection | Hand | Dead-smooth | 4 |
| | Inspection | Square | Smooth | 8 |
| | Inspection | Round | Smooth | 8 |

## 4.—Filing department.

FILES USED.

| Component. | Operation. | Kind. | Cut. | Length. |
|---|---|---|---|---|
| | | | | *Inches.* |
| Bayonet | Second filing | Hand | Skew-cut, smooth | 7 |
| | Second filing | Half-round | Bastard | 5 |
| | Second filing | Three-square | Second cut | 4 |
| | Second filing | Half-round | Smooth | 8 |
| | Assembling | Square | Second cut | 8 |
| Bayonet clasp | Jigging | Round | Second cut | 6 |
| | Jigging | Square | Bastard | 11 |
| | Filing | Hand | Skew-cut, smooth | 10 |
| | Filing | Hand | Skew-cut, smooth | 6 |
| | Filing | Half-round | Smooth | 6 |
| | Filing | Hand | Smooth | 6 |
| | Filing | Hand | Second cut | 6 |
| Receiver | First rotary filing | Rotary | Bastard (diameter [illegible] inch) | 1[illegible] |
| | Second rotary filing | Rotary | Bastard (diameter [illegible] inch) | 1[illegible] |
| | Third rotary filing | Rotary | Second cut (diameter $\frac{5}{16}$ inch). | 1 |
| | Third shaving | Half-round | Second cut | 7 |
| | Third shaving | Pillar | Second cut (cut on one edge). | 7 |
| | Fitting | Cant | Smooth | 7 |
| | Fitting | Hand | Smooth | 7 |
| | Second filing | Flat | Skew-cut, second cut | 8 |
| | Second filing | Flat | Skew-cut, smooth | 9 |
| | Second filing | Round | Smooth | 6 |
| | Second filing | Round | Dead-smooth | 6 |
| | Second filing | Hand | Second cut | 6 |
| | Second filing | Half-round | Dead-smooth | 6 |
| | Second filing | Pillar | Skew-cut, smooth | 8 |
| | Second filing | Half-round | Bastard | 8 |
| | Second filing | Half-round | Smooth | 8 |
| | Numbering | Flat | Skew-cut, smooth | 9 |
| | Third filing | Hand | Second cut | 6 |
| | Third filing | Cant | Second cut | 4 |
| | Third filing | Pillar | Second cut (beveled edges). | 8 |

*Files used at the National Armory, &c.*—Continued

| Component. | Operation. | Kind. | Cut. | Length. |
|---|---|---|---|---|
| | | | | *Inches.* |
| Receiver | Third filing | Pillar | Second cut (cut on one edge). | 7 |
| Breech blocks | Second filing | Flat | Skew-cut, second cut | 9 |
| | Second filing | Flat | Skew-cut, smooth | 9 |
| | Second filing | Round | Smooth | 6 |
| | Second filing | Round | Dead-smooth | 6 |
| | Second filing | Half-round | Smooth | 7 |
| | Second filing | Flat | Bastard | 8 |
| | Second filing | Hand | Skew-cut, smooth | 8 |
| | Second filing | Flat | Second cut | 8 |
| | Finishing | Half-round | Smooth | 6 |
| | Finishing | Hand | Smooth | 6 |
| | Finishing | Hand | Second cut | 6 |
| Cam latch | Second filing | Half-round | Dead-smooth | 6 |
| | Second filing | Hand | Second cut | 4 |
| | Second filing | Pillar | Bastard | 10 |
| | Second filing | Hand | Skew-cut, second cut | 10 |
| | Second filing | Hand | Second cut | 5 |
| Thumb piece | Filing | Half-round | Dead-smooth (high back) | 6 |
| | Filing | Half-round | Smooth | 7 |
| | Filing | Hand | Skew-cut, second cut | 9 |
| Extractor | Jigging | Three-square | Bastard | 8 |
| | Jigging | Three-square | Smooth | 7 |
| | Jigging | Hand | Skew-cut, smooth | 8 |
| | Jigging | Hand | Dead-smooth | 6 |
| | Filing | Flat | Skew-cut, smooth | 8 |
| | Filing | Cant | Smooth | 4 |
| Hinge pin | Riveting | Pillar | Skew-cut, second cut | 10 |
| | Riveting | Half-round | Dead-smooth | 6 |
| Rear-sight base | Filing | Hand | Skew-cut, second cut | 10 |
| | Filing | Flat | Skew-cut, smooth | 10 |
| | Finishing | Hand | Dead smooth | 5 |
| | Finishing | Half-round | Dead-smooth | 5 |
| | Finishing | Cant | Smooth | 5 |
| | Second shaving | Half-round | Second cut (high back) | 9 |
| | Second shaving | Pillar | Smooth | 9 |
| | Second shaving | Cant | Smooth | 5 |
| Rear-sight leaf | First filing | Hand | Skew-cut, second cut | 9 |
| | First filing | Flat | Skew-cut, second cut | 8 |
| | Second filing | Hand | Skew-cut. second cut | 8 |
| | Jigging | Pillar | Bastard (cut on edges) | 11 |
| | Jigging | Hand | Bastard | 10 |
| | Jigging | Hand | Skew-cut, smooth | 10 |
| | Jigging | Flat | Dead-smooth | 8 |
| | Jigging | Hand | Dead-smooth | 6 |
| | Jigging | Hand | Skew-cut, smooth | 7 |
| | Jigging | Hand | Skew-cut, smooth | 6 |
| | Jigging | Hand | Dead smooth | 5 |
| | Finishing | Cant | Dead smooth | 4 |
| Rear-sight buckhorn plate. | Filing | Hand | Skew-cut, second cut | 10 |
| | Filing | Pillar | Skew-cut, second cut | 10 |
| | Filing | Pillar | Skew-cut, second cut | 8 |
| | Filing | Hand | Dead-smooth | 5 |
| | Filing | Half-round | Dead-smooth | 5 |
| | Filing | Hand | Skew-cut, second cut | 5 |
| | Filing | Hand | Skew-cut, smooth | 5 |
| Rear-sight slide plate | Filing | Hand | Skew-cut, second cut | 10 |
| | Filing | Pillar | Skew-cut, second cut | 8 |
| | Filing | Pillar | Dead-smooth | 7 |
| | Filing | Hand | Dead-smooth | 6 |
| Rear-sight slide block | Cornering | Hand | Dead-smooth | 11 |
| | Cornering | Pillar | Dead-smooth | 7 |
| | Cornering | Pillar | Skew-cut, dead-smooth | 7 |
| Rear-sight slide spring | Adjusting and curving | Hand | Smooth | 5 |
| | Adjusting and curving | Pillar | Smooth | 10 |
| Rear sight | | Cant | Smooth | 4 |
| Upper band | Burring | Round | Dead-smooth | 9 |
| Band spring | Filing | Flat | Second cut | 8 |
| | Burring | Three-square | Smooth | 6 |
| Guard bow | Swiveling | Square | Skew-cut { 2 sides safe. 1 side sm'h. 1 side bst'd. } | 11 |
| Guard plate | Fitting | Flat | Second cut (thin) | 4 |
| Bridle | Filing | Hand | Smooth | 10 |
| | Filing | Flat | Skew-cut, second cut | 10 |
| | Filing | Half-round | Smooth | 7 |
| | Filing | Cross | Smooth | 8 |
| Hammer | Filing | Hand | Skew-cut, smooth | 10 |
| | Filing | Half-round | Bastard | 8 |
| | Filing | Half-round | Second cut | 6 |
| | Finishing | Half-round | Smooth | 6 |

*Files used at the National Armory, &c.*—Continued.

| Component. | Operation. | Kind. | Cut. | Length. |
|---|---|---|---|---|
| | | | | *Inches.* |
| Lock plate | Filing | Hand | Smooth | 12 |
| | Filing | Hand | Second cut | 12 |
| | Filing | Bevel hand | Second cut | 10 |
| | Filing | | Skew-cut, bastard | 12 |
| | Filing | Hand | Skew-cut, smooth | 12 |
| | Stamping | Hand | Skew-cut, smooth | 12 |
| | Finishing | Hand | Dead-smooth | 10 |
| | Finishing | Half-round | Dead-smooth | 6 |
| | Finishing | Flat | Smooth | 6 |
| Main-spring | Adjusting | Hand | Smooth | 8 |
| | Adjusting | | Dead-smooth | 8 |
| | Adjusting | Hand | Smooth | 9 |
| | Adjusting | Hand | Smooth | 12 |
| | Adjusting | Hand | Skew-cut, hook-file knife-edge, smooth. | 10 |
| | Adjusting | Hand | Smooth-cut rotary file, for hook. | 2 |
| Main-spring swivel | Filing | Hand | Bastard | 11 |
| | Filing | Flat | Skew-cut, smooth | 6 |
| | Filing | Hand | Smooth | 6 |
| Sear | Filing | Hand | Bastard | 10 |
| | Filing | Flat | Skew-cut, second cut | 10 |
| | Filing | Round | Bastard | 12 |
| | Filing | Hand | Skew-cut, smooth | 6 |
| | Filing | Three-square | Second cut | 6 |
| | Filing | Half-round | Smooth | 6 |
| | Filing | Three-square | Bastard | 9 |
| | Filing | Three-square | Second cut | 6 |
| | Filing | Rotary | Second cut (diam. $\frac{5}{16}$ in.) | 2 |
| Sear spring | Adjusting | Knife | Smooth | 7 |
| | Adjusting | Square | Second cut | 6 |
| | Adjusting | Hand | Smooth | 8 |
| | Adjusting | Half-round | Dead-smooth | 7 |
| Tumbler | First filing | Pillar | Second cut | 11 |
| | First filing | Flat | Skew-cut, smooth | 10 |
| | First filing | Pillar | Bastard | 11 |
| | First filing | Half-round | Second cut | 8 |
| | First filing | Half-round | Smooth | 8 |
| | First filing | Half-round | Second cut (high back) | 6 |
| | First filing | Round | Second cut | 8 |
| | First filing | Flat | Skew-cut, smooth | 8 |
| | First filing | Half-round | Dead-smooth | 8 |
| | First filing | Knife | Second cut | 8 |
| | First filing | Knife | Bastard | 8 |
| | First filing | Hand | Dead-smooth | 6 |
| | First filing | Cant | Smooth | 5 |
| | First filing | Cant | Smooth | 7 |
| | First filing | Cant | Dead-smooth | 7 |
| | First filing | Half-round | Dead-smooth | 5 |
| | First filing | Three-square | Second cut | 8 |
| | First filing | Hand | Smooth | 5 |
| | First filing | Flat | Second cut | 4 |
| | First filing | Saw, beveled | Second cut | 7 |
| | First filing | Flat, beveled | Second cut | 8 |
| | Second filing | Three-square | Skew-cut, smooth, one safe side. | 8 |
| | Second filing | Half-round | Dead-smooth | 6 |
| | Second filing | Half-round | Smooth, high back | 6 |
| | Second filing | Half-round | Dead-smooth (No. 6) | 4 |
| | Second filing | Half-round | Dead-smooth (No. 4) | 4 |
| | Second filing | Half-round | Smooth, high back | 8 |
| Lock | Assembling | Flat | Smooth | 10 |
| | Assembling | Hand | Dead-smooth | 4 |
| | Assembling | Flat, thin | Dead-smooth | 4 |
| | Assembling | Hand | Second cut | 4 |
| | Assembling | Cant | Second cut | 4 |
| Ramrod stop | Filing | Flat | Smooth | 8 |
| | Filing | Half-round | Dead-smooth | 6 |
| Butt-plates, carbine | Fitting and draw-filing | Half-round | Smooth | 8 |
| | Fitting and draw-filing | Half-round | Dead smooth | 6 |
| | Fitting and draw-filing | Three-square | Second cut | 6 |
| | Fitting and draw-filing | Cross | Smooth | 8 |
| | Fitting and draw-filing | Half-round | Dead smooth | 8 |
| Butt-plate cover, carbine | Burring | Half-round | Smooth (No. 21) | 6 |
| Guard-bow, carbine | Filing | Half-round | Bastard | 12 |
| | Filing | Half-round | Bastard | 9 |
| | | Round | Smooth | 6 |

*Files used at the National Armory, &c.*—Continued.

APPENDAGES.

| Component. | Operation. | Kind. | Cut. | Length. |
|---|---|---|---|---|
| | | | | *Inches.* |
| Headless shell extractor | Filing | Three-square | Dead-smooth | 5 |
| Screw-driver blade, large | Filing | Round | Second cut | 6 |
| | Filing | Hand, thin | Second cut | 5 |
| | Jigging | Pillar | Skew-cut, second cut | 10 |
| | Jigging | Square | Second cut | 8 |
| Screw-driver, comb. M 79 | Assembling | Flat | Skew cut, second cut | 12 |
| | Assembling | Flat | Second cut | 9 |
| | Finishing | Hand | Second cut | 9 |
| Steel bayonet scabbards | Burring | Flat | Second cut | 10 |
| | Burring | Half-round | Second cut | 6 |
| | Inspecting | Hand | Second cut | 5 |
| | Inspecting | Half-round | Dead-smooth | 4 |
| | Inspecting | Hand | Dead-smooth | 4 |
| | Inspecting | Square | Smooth | 7 |
| | Inspecting | Cant | Dead-smooth | 4 |
| | Inspecting | Hand | Dead-smooth | 6 |
| | Inspecting | Flat | Skew-cut, second cut | 10 |
| | Inspecting | Flat | Dead-smooth | 6 |
| | Inspecting | Hand | Smooth | 6 |
| | Inspecting | Half-round | Dead-smooth | 6 |
| | Inspecting | Half-round | Second cut (low back) | 8 |
| | Inspecting | Flat | Smooth | 10 |
| | Inspecting | Hand | Dead-smooth | 4 |
| | Inspecting | Flat, thin | Dead-smooth | 4 |
| | Inspecting | Hand | Second cut | 4 |
| | Inspecting | Cant | Second cut | 4 |
| | Saw-filing | Three-square | | 3 |
| | Saw-filing | Three-square | | 4 |
| | Saw-filing | Three-square | | 5 |
| | Saw-filing | Three-square | | 6 |

5.—SPECIAL FILES MADE AT THE NATIONAL ARMORY FOR FILING SHOP.

8-inch flat, skew-cut, smooth, beveled edges 49°, for tumbler notches.
10-inch hand oval, $\frac{3}{4}$ inch wide, coarse, smooth, for main springs.
10-inch half-round, high back, $\frac{1}{2}$ inch wide, smooth, for rear-sight base hinge.
9-inch pillar, oval, $\frac{5}{8}$ inch wide, second cut, for sear springs.
10-inch pillar, slightly oval, $\frac{1}{2}$ inch wide, skew-cut, for screw-driver large blade.
11-inch pillar, $\frac{1}{2}$ inch wide, .27 inch thick, cut on two edges bastard, for jig-filing slot of rear-sight leaf.
10-inch pillar, skew-cut, smooth, beveled edges 71°, for buckhorn.
10-inch pillar, skew-cut, smooth, $\frac{1}{2}$ inch wide, for top of rear-sight base front of ears.
7-inch pillar, second cut on one edge, $\frac{1}{2}$ inch wide, .15 inch thick, for receiver under hinge.
6-inch pillar, skew-cut, beveled edges 69°, for under ends of buckhorn.
8-inch pillar, skew-cut, second cut $\frac{7}{16}$ inch wide, for burring rear-sight base inside after knurling.

6.—STOCKING SHOP.

FILES USED.

| Component. | Operation. | Kind. | Cut. | Length. |
|---|---|---|---|---|
| | | | | *Inches.* |
| Stock | Shaping | Round | Second cut | 7 |
| | | Flat | Second cut | 12 |

*Files used at the National Armory, &c.*—Continued.

7.—CARPENTER SHOP.

| Component. | Operation. | Kind. | Cut. | Length |
|---|---|---|---|---|
| | | | | *Inches.* |
| | | Flat | Second cut | 8 |
| | | Flat | Skew-cut, smooth | 11 |
| | | Three-square | Second cut | 8 |
| | | Three-square | Skew-cut, second cut | 3 |
| | | Three-square | Skew-cut, second cut | 4 |
| | | Three-square | Skew-cut, second cut | 5 |
| | | Three-square | Skew-cut, second cut | 6 |
| | | Flat, thin | Dead-smooth | 4 |

8.—PATTERN SHOP.

| Component. | Operation. | Kind. | Cut. | Length |
|---|---|---|---|---|
| | Pattern making | Flat | Bastard | 12 |
| | Pattern making | Flat | Skew-cut, second cut | 10 |
| | Pattern making | Square | Wood rasp | 11 |
| | Pattern making | Round | Wood rasp | 11 |
| | Pattern making | Cross | Wood rasp | 11 |
| | Pattern making | Half-round | Wood rasp | 10 |
| | Pattern making | Half-round | Wood rasp | 8 |
| | Pattern making | Flat | Stockers, soft, bastard | 12 |
| | Pattern making | Half-round | Second cut | 8 |
| | Pattern making | Half-round | High back, smooth | 7 |
| | Pattern making | Hand | Bastard | 8 |
| | Pattern making | Half-round | Second cut | 7 |
| | Pattern making | Hand | Smooth | 9 |
| | Pattern making | Half-round | Second cut | 9 |
| | Pattern making | Three-square | Second cut | 7 |
| | Pattern making | Round | Smooth | 8 |
| | Pattern making | Flat | Skew-cut, second cut | 9 |
| | Pattern making | Hand | Smooth | 4 |
| | Pattern making | Round | Wood rasp | 8 |
| | Pattern making | Cross | Second cut | 12 |
| | Pattern making | Cross | Second cut | 8 |
| | Pattern making | Cross | Second cut | 7 |

# PART V.

## I.—GLOSSARIAL DESCRIPTION.

The terms defined and files described under this heading have been principally compiled from Nicholson's Treatise on Files and Knight's Mechanical Dictionary.

*Angular file.*—A locksmith's file for working into the corners of the wards of keys.

*Arm file.*—A name from the German—a hand file.

*Back.*—A term used to describe the convex side of half-rounds, cabinets, pit-saw, and other files of similar cross-sections.

*Balance-wheel file, or swing-wheel file* (*Horology*).—A file adapted to cut out the sectors from the circular steel plate which forms the blank for the balance-wheels.

*Band-saw file.*—A small, tapering, blunt file; triangular section, edges blunted; considerably finer cut than hand-saw files.

*Barrel-hole file.*—A watchmaker's file.

*Bastard file.*—One of a grade between the *rough* and the *smooth* in respect to the relative prominence and coarseness of the teeth. The angle of the chisel in cutting the bastard file is about 10° from the perpendicular.

*Blank.*—See *File blank*.

*Blunt file.*—A file which has but a slight taper. It is a grade between the regular *taper* and the *dead parallel* file.

*Boot-heel file.*—Same as flat file, except lighter. One side, *rough* single cut; the other, *coarse* double-cut. Length, 12 to 18 inches. Used by boot and shoe manufacturers for roughing down pegs and nails in finishing the bottoms of boots and shoes.

*Bow file.*—A curved file; a riffler.

*Brass bastard file.*—A file having the *over-cut* very open and with considerable obliquity, while the *up-cut* is quite fine and runs nearly straight across the file.

*Brass coarse file.*—A file with very open *over* and *up-cut*, made to file rapidly. Good for rough work.

*Bread rasp.*—A rasp used by bakers in removing the burned crust of loaves and rolls, especially French rolls.

*Cabinet file.*—A smooth single-cut file, used in wood-working, especially by furniture-makers and joiners. Tapering from middle to point. Convex sides little less than one-fifth part of a circle. Length, from 6 to 14 inches, usually 8, 10, and 12 inches.

*Cant file.*—A file having the shape of an obtuse-angled triangle in its transverse section; used in filing the inner angles of spanners and wrenches for bolts with hexagonal and octagonal heads. The salient angle derived from the hexagon, known as six-canted.

*Carlet.*—A three-square, single-cut file or float, used by comb-makers.

*Checkering file.*—A compound file, consisting of two files riveted together, and whose edges project unequally, so that one acts as a spacer in check-working the *small* of gun-stocks, &c. Also used for checking pistol-grips. Used by cutlers in checking their work. Called also *double file.* Cooper's double file has a re-entrant angle, used for sharpening pencils. Checking or double files have the edges V-shaped and cut.

*Circular file.*—A circular saw or serrated disk, adapted to run on a spindle or mandrel, and used in cutting teeth of cog-wheels.

*Cobler.*—A bent rasp for straitening the shaft of a ramrod.

*Concavo-convex file.*—A file with curved faces, respectively concave and convex, made by cutting a flat file and then bending it into shape between dies. The mode is the invention of Sir John Robison, president of the Scottish Society of Arts, and is designed to enable the convex side to be cut like a flat file by a chisel which reaches across the edge, instead of cutting numerous courses, which usually cover the convex surfaces of files.

*Cotter equaling.*—A file having same section, cut, and size as cotter taper, but made *equaling.* Of limited demand; used for same purposes as *flat-equaling* and *slotting* files.

*Cotter file.*—A narrow file with strait sides, used in filing grooves for cotters, keys, or wedges.

*Cotter taper file.*—A file made from pillar section, but advancing 2 inches in its length on pillar sizes: thus, a 6-inch pillar making an 8-inch cotter, &c. Cut double, and has considerable taper on both its sides and edges. Sometimes called *taper cotter.* Seldom ordered.

*Cross-cut.*—The second series or course of teeth on a double-cut file. Another name for the *up-cut* or *top-cut.*

*Cross file.*—A file used in dressing out the arms or crosses of fine wheels. It has two convex faces of different curvatures. It is also known as a *double half-round* file.

*Cutting file.*—The toothed cutter of a gear-cutting engine.

*Dead-smooth file.*—A file whose teeth are of the finest and closest

quality. The angle of the chisel in cutting is about 4° from the perpendicular. Sometimes called a *superfine* file.

*Dentist files.*—These are numerous and various in design, but are not given here.

*Doctor file.*—A smooth, double-cut file, made equaling in shape from *flat* and *hand*-file sections, for the use of calico printers. Length usually 14 inches. It is used for straitening the edges of "doctor plates."

*Double-cut file.*—One which has *two* rows of teeth, crossing each other at an angle, in contradistinction to the *single-cut* or *float*, which has but one row.

*Double-ender hand-saw file.*—A short hand-saw file, in which the one end is used as a tang to hold the handle until worn, when the handle is changed and the other end used for filing.

*Double file.*—See *Checkering file.*

*Double half-round file.*—A file whose sides are curved, the edges forming cusps, the arcs of the sides being less than 180°; used for dressing or *crossing out* balance-wheels, and hence known as a cross file. The convex edges have usually different curvatures. See *Cross file.*

*Double-tang file.*—A file with a tang at each end, to adapt it to receive the handles. Applied to rubbers or other very heavy files. To be used by two persons.

*Dovetail file.*—A thin file with a tin or brass back, like the stiffener of a dovetail or tenon-saw.

*Endless-screw file.*—A watchmaker's file.

*Entering file.*—A narrow, flat file with considerable taper, to enable it to enter and open a groove, which may be finished by a cotter file.

*Equaling file.*—A flat file which has a constant thickness, but may taper a little as to width. The watch and clock equaling files have the slight taper. Nicholson uses this term "to describe a *blunt* file upon which is produced an *exceedingly* slight belly or curvature extending from point to tang, the file *apparently* remaining blunt. The term may be applied to either the edges or sides of files or to both.

*Feather-edge file.*—A file with an acute edge, the cross-section of the file being an isosceles triangle with a short base; a knife file; little used now.

*Finishing second-cut file.*—In this the first or *over-cut* is very fine, and contrary to the general rule has the least obliquity; the *up-cut* is the coarser of the two cuts and has an unusual obliquity; so made to finish finer, free itself, and prevent clogging and gliding.

*File blank.*—A piece of soft steel, shaped and ground ready for cutting to form a file.

*File carrier.*—A tool-holder like the stock of a frame-saw, and used to mount a file in a manner similar to that of the saw in the case cited.

*File chisel.*—A cold-chisel used in cutting files. See description elsewhere.

*File cleaner.*—A scratch-brush of wire; a thin brass edge which acts as a rake. To remove wood, dip the file in hot water to swell the wood; it is then removed by a hand brush; the warmth evaporates the moisture.

*File-cutting machine.*—A machine by which files are cut automatically. See description.

*File rasps.*—Made flat and half-round. The *flat* have one side punched, bastard, rasp; the other cut, bastard, double-cut; the edges coarse, single-cut; used by horseshoers for nice work. The 8, 10, and 12-inch half-round are made with back, rasp, and flat side file-cut; used by farmers and wheelwrights.

*File sharpening.*—Worn files are first cleaned by hot water and soda,

then placed in connection with the positive pole of a battery in a bath composed of 40 parts of sulphuric acid, 80 parts of nitric acid, and 1,000 parts of water. The negative pole is formed of a copper spiral surrounding the files, but not touching them; the coil terminates in a wire which rises toward the surface. When the files have been ten minutes in the bath they are taken out, washed and dried, when the hollows will be found to have been attacked in a very sensible manner; but should the effect not be sufficient they are replaced for the same period as before. Two operations are sometimes necessary, but rarely.

*File stripper.*—"A machine in which a worn-out file, after being softened by heat and slow cooling, is smoothed to prepare it for being recut. In the example, the file is held by adjustable jaws upon a slightly rotating bed supported by springs. The cross-bar to which the stripping tool is attached is connected at each end by a connecting rod with a crank upon the end of the driving-shaft, and which may be elevated to raise the stripper off the file through the instrumentality of a rock-shaft and a system of levers at the other end." (*Knight.*)

*Filing block.*—"A block of apple, pear, or boxwood, gripped in the jaws of a vise, and having grooves of varying depth in which small rods, bars, or wires may be laid to be filed. The wire is shown as grasped by a hand vise." (*Knight.*)

*Filing machine.*—1. A machine used in the mint to reduce the weight of coin planchets when above the standard. The pieces are laid parallel in a trough and their edges rest upon a cylindrical file, whereby a portion of metal is removed, the pieces rotating as the work proceeds in order to preserve their circularity. 2. A machine in which a file is mounted as a jig-saw; or to reciprocate in a manner similar to that of a file in the hands of a workman. In the example, the file receives vertical reciprocation from a pitman whose cross-head has a horizontal slot traversed by a crank-pin on a rotating disk. The table is pivoted and has a semicircular rack which is engaged by a screw-gear to incline the table.

*Filings separator.*—A machine in which filings of iron and copper are separated by exposure to magnets which are brought into contact with all of the particles and select, retain, and remove the iron particles from those of brass and copper, so that the latter may be used for remelting. There are several forms of machines for the purpose.

*Flat file.*—A file of rectangular section and wider than its thickness. When bellied it is known as a *taper* file; when the size is maintained from end to end it is known as a *parallel* file; when 10 inches or less in length, generally made taper; when longer, full taper. Double-cut, four varieties of teeth, largest proportion being bastard-cut; flat bastard, most common file in use, employed on all coarser kinds of filing. The *flat, second cuts*, and *smooths* also in general use for finishing metal for the dead smooth file and emery wheel.

*Flat equaling file.*—A double-cut, principally second-cut or smooth, made equaling in shape. Used for finishing wide mortises on crossheads of engines to prepare them for gib and key.

*Flat wood file.*—A taper file made from the "flat" sections, having a coarse double-cut; the sizes range from 8 to 16 inches in length. They are in regular but limited use at the present day.

*Float.*—A single-cut file, or one in which the teeth are parallel and unbroken by a second row of crossing-teeth. The usual horizontal obliquity of the teeth relative to the central line of files is 55°, but single-cut files are much less inclined, and the teeth of *floats* are sometimes square across the face of the file. The floats of comb-makers and ivory-

carvers are made of various shapes, and those of the former are known by their specific names as *graille*, *found*, *carlet*, *topper*. The teeth have a forward inclination of about 15° and are made by a file, not by a chisel. They are of a lower temper than usual, and are sharpened by a burnisher.

*Found.*—A three-square, single-cut file or float, with one very acute angle; used by comb-makers.

*Frame-saw file.*—The *pit-saw* file is in some places called the frame-saw file; it is used to file frame-saws, which in shape resemble very nearly pit-saws.

*Full-taper file.*—In Nicholson's classification, taper file is defined to be a file the *point* of which is more or less reduced in size by a curved taper extending from one-half to two-thirds the length of the file from the point. By *full taper* he describes any file which is not only tapered at the *point*, but in which a slight curvature is continued to the *heel*, its greatest cross-section being at or near the middle of the file. The term *full taper* may be applied to either the edges or sides of files, or to both; though it is usually applied to the sides, and is sometimes called *bellied.*

*Gang-edger file.*—A single-cut blunt file from mill sections. It is shorter than a mill file, being 8 inches long with 10-inch mill section. Used for sharpening the gangs of saws employed for edging boards in the machines known as "gang-edgers" without removing the saws from their arbor; also for sharpening the knives of rotary planers while on the cylinder.

*Gin-saw file.*—Made from *knife* sections and tapered, cut single on sides, and thin edge, like hand-saw file; used for filing the saws used in cotton-gins. Length usually 3½ and 4 inches.

*Graille.*—A single-cut file or float, having one curved face and a strait one, used by comb-makers.

*Gulleting file.*—This is a round, blunt, single-cut saw file.

*Half-round file.*—A file flat on one side and rounding on the other. The curve usually varies from the half to the twelfth of a circle, but the name half-round is indiscriminately applied. Files with the larger curvature are known as *full* half-rounds, others as *flat* half-rounds. The convex side can be used on a variety of concave work. Flat side is used for general purposes; the acute angle of edges enable it to be used where flat, square, or three-square files cannot enter.

*Half-round wood files.*—These files are similar in section and tapered like the half-rounds; length usually from 10 to 14 inches. *Cut coarse, double:* for the use of wood-workers.

*Half-thick file.*—A large, coarse file with three flat and one rounded side. It is used as a *rubber* file for coarse work.

*Hand file.*—A somewhat generic term including most forms of files. It is cut *double;* one edge cut *single*, other edge left *safe*. Full tapered on sides and nearly parallel in width. Bastard most common grade: second cut and smooth good deal used; and for smaller sizes, dead smooth. This file is generally preferred by machinists and engineers for finishing flat surfaces, owing to its having one safe edge.

*Hand equaling file.*—The hand sections sometimes made equaling. The cut and uses are about the same as *flat equaling file.*

*Hand-saw blunt.*—Not a common file. Edges set and cut, single or double, like hand-saw taper file.

*Hand saw taper single cut.*—A tapered, triangular file, ranging in length from 2 to 12 inches (by half inches below 6-inch), with 3 to 5 inches as the most common. The edges are first blunted or "set" and then cut—then sides stripped and cut.

*Hand-saw taper double cut.*—Similar to the above, except they are double cut. The edges are set and cut like the single-cut saw files. The three sides usually second cut; lengths usually from 3 to 6 inches.

*High-back file.*—A file with greater curvature than the half-round file, usually tapered but sometimes blunt. They are double-cut.

*Hollow-edge file.*—A file with a concave edge for dressing teeth or small-gear wheels and pinions.

*Hook-tooth file.*—A saw file, blunt, half-round sections, from 6 to 12 inches long. Bastard or second cut, single; used for filing "hook-tooth" saws.

*Hopped.*—A term used by file-makers to represent a very coarse or *open* spacing of the teeth (sometimes greater than ½-inch), generally applied to the backs of half-rounds and to the edges of rectangular sections.

*Joint file.*—A small file without taper and circular in its cross-section. It is used for dressing out the holes for the joint wire in snuff-boxes, &c., and for preparing the apertures for the pintles of hinges.

*Key file.*—A flat file having a constant thickness, and used in filing the ward-notches in keys.

*Kit files.*—An assortment of twelve very small files, sold for shoemakers' use in repairing their tools.

*Knife blunts.*—Files similar to knife files, which see.

*Knife file.*—A file with a very acute edge, the cross-section being an isosceles triangle with a short base; known also as a feather-edge file. It is used in cutting narrow notches, and in making an entering kerf for saws and for files with broader edges, also in beveling or chamfering the sides of narrow grooves.

*Lead-float file.*—A very coarse single-cut file for use on soft metals, lead, pewter, &c. Teeth very open to prevent clogging, and having small horizontal obliquity to prevent gliding; usually made in 8, 10, and 12 inch *flats* and *half-rounds;* used chiefly by plumbers.

*Lightning file.*—A file for "lightning saws"; obtuse angle smaller than for cant file; is derived from the pentagon, known as "five-canted."

*Lock file.*—A slitting file knife-shaped, for cutting out the wards in the bit of the key.

*Machine mill file.*—A file adapted to a machine used for filing gang mill saws in lumber mills, edges generally square, cut like mill files.

*Marble-worker's files.*—The files and rasps of the marble-worker and sculptor are of various shapes and grades of fineness.

The principal kinds are:

1. Half-round rasp.
2. Round file.
3. Flat file.
4. German half-round rasp.
5. Safe-side rasp.
6. Perforated file. (*Hiram Powers.*)

*Marking file.*—See Nicking file.

*Middle-cut file.*—A file whose teeth have a grade of coarseness between the *rough* and *bastard.*

*Mill blunt.*—A mill file sometimes made, generally double-cut; seldom below 8 inches in length; used in machine shops for working out narrow mortises; edges sometimes ground to suit the gullets in the teeth of saws upon which they are to be used, and cut *single;* called equaling files by some authors.

*Mill file.*—A file with a slight taper both in the thickness and width, from the middle to the point; used for sharpening mill saws, hence the name. Usually made bastard or *second-cut single,* and cut on both faces

and edges. Occasionally made *second-cut double* to order, and with one or two round edges.

*Mill-pointing file.*—Like a mill file, except it has a narrow point, used for filing saws.

*Molding file.*—A file with a cavity adapted to dress and finish molded surfaces. It is made by a swage and afterward cut.

*Nail file.*—A small, flat, single-cut file for trimming the finger nails. It is a part of the furniture of the dressing-case, or is cut on the blades of nail scissors, or on one small blade of a pocket-knife.

*Nicking file.*—A small, tapered, half-round file for making nicks in the heads of screws. Convex side *smooth* cut, flat side uncut; sharp edge used in marking off work from gauges; sometimes called marking file.

*Oval file—Oval-dial file.*—A file whose cross-section is elliptical or oval; used sometimes as a *gulleting* file. The oval-dial file is used by watchmakers.

*Over-cut.*—The first course of chisel cuts or teeth having a horizontal obliquity with the central line of the file, ranging from 35° to 55°.

*Parallel file.*—One which has no taper, but preserves its size from tang to point. One which is flat and strictly correct is known as a *dead-parallel* file. A round file without taper is a *joint* file.

*Parting tool.*—A rasp of peculiar shape, coarse or fine in grain, and used by marble-workers.

*Perforated file.*—A file invented by Hiram Powers, having openings through which the abraded material is allowed to escape. It is especially intended for sculptor's use.

*Piercing file.*—A sharp and narrow file, to enlarge a narrow-drilled hole.

*Pillar file.*—A narrow, thin, flat, hand file with one *safe edge;* sides generally full taper; double-cut.

*Pinion file (watch making).*—A knife file employed by watch-makers.

*Pit-saw file.*—A file used for sharpening the teeth of pit-saws, 5 to 8 inches in length.

*Pivot file (watch-making).*—A fine file used in dressing pivots on the arbors of watches.

*Potance file—Pottance file.*—A small hand file with parallel and flat sides; so called by Lancashire makers.

*Quannet.*—The flat file of the comb maker, having a handle at one side, so as to use like a plane. The teeth incline 15° forward, and are made by a triangular file, not by a chisel.

*Rasp.*—An abrading tool of the nature of a file, but having instead of chisel-cut teeth its surface dotted with separate protruding teeth, formed by the indentations of a pointed punch. It is used almost exclusively upon comparatively soft substances, as wood, horn, and the softer metals. The teeth of cabinet-maker's and farrier's rasps are cut in lines sloping from left to right; those for last-makers and some others in the reverse direction; for gunstockers and some others the teeth are disposed in curved or crescent-shaped lines. These distinctions are unnecessary, the only requisite being that each tooth should be intermediate between the two in front of it so as not to form furrows in the work. When visited by Captain Cook, the Tahitians were using a piece of coral for a rasp.

*Rasp-cutting machine.*—A machine for cutting rasps, resembling that used for cutting files.

*Rasp punch.*—A tool for cutting the teeth of rasps. It is held in the left hand of the workman at a suitable angle to the face of the blank.

and struck with a mallet or hammer. It has a triangular, pyramidal point to form the teeth of the rasp.

*Rasper* (*baking*).—A file for rasping the burnt surface from loaves of bread. See *Bread rasp*.

*Rat-tail file.*—A small tapering file, circular in cross-section.

*Reaper file.*—A file for sharpening knives of reaping and mowing machines; trapezoidal in section; slightly tapered, single-cut on sides, beveled edges, left *safe*; length 7 to 10 inches.

*Riffler.*—A file with a side so convex as to operate in shallow depressions; used by sculptors, carvers, and gunstockers. They are made of various convexities and curvatures to adapt them to varying surfaces. Rifflers are usually made of steel, but sometimes of wrought iron and case-hardened, so that their shape may be modified to a certain extent by bending on a block of lead with a mallet. Double-ended rifflers are also made.

*Roller file.*—A file designed for use in a machine adapted to filing the plates of feed-rollers in cotton-spinning machinery. The sides are planed to the required angle; length about 4 inches; sizes, Nos. 1 and 2. No. 1 having the thinnest edges.

*Rotary files.*—These are short, cylindrical, round, tapering, or irregular-shaped files, designed for rapid work in filing out and enlarging cavities and for other purposes. They are clamped in a chuck attached to a small pully-arbor, which is belted and run by power, or they may be used in a profiling machine.

*Rough file.*—A file with heavy deep cuts. The angle of the chisel in cutting is about 12° from the perpendicular. The number of teeth to the inch of a rough file depends on the length of the file in inches. (See table.) These files are often termed "ruffs" in the trade.

*Round blunt file.*—A file made of the same sectional sizes as the round, and are often 18 or 20 inches in length. The principal cut is the *bastard double*. These and the round files possess greater strength than the half-round of same sectional curvature; used on heavy work, such as engine and bridge building, in railroad shops and shipyards.

*Round-edge file.*—A file with a convex edge, for filing out or dressing the interdental spaces of gear-wheels.

*Round file.*—A file circular in cross-section, and generally tapering. Lengths from 2 to 16 inches.. Small taper files of this description are known as *rat-tail* files. Small round files, without taper, are known as joint files, being used for filing out apertures for joint wires and pintles of hinges. These files are used for *gulleting* saws and for enlarging round holes, &c.

*Round-joint file.*—A kind of clock-maker's file.

*Round-off file.*—A small parallel half-round file, whose convex side is *safe* or uncut, and having a pivot at the end opposite the tang. It is used for rounding or pointing the teeth of wheels made originally with square notches. The pivot enables it to be readily twisted in the fingers to allow it to sweep round the curve of the tooth under treatment.

*Rubber file.*—A heavy, fish-bellied file, designated by weight, which varies from four to fifteen or twenty pounds. They are of square or triangular section and used for coarse work. When they have three flat faces and one rounded they are known as *half-thick* files.

*Safe-edge file.*—One having a smooth edge which does not cut a surface against which it impinges.

*Saw file.*—A file adapted for saws; triangular in cross-section for hand saws and flat for mill saws. The fineness of the file depends upon the character of the work.

*Screw-head file.*—A feathered-edge file for nicking screw heads.

*Second-cut files.*—A file whose teeth have a grade of coarseness between the *bastard* and *smooth*. The angle of the chisel in cutting is about 7° from the perpendicular.

*Set.*—The process of filing off or blunting the sharp edges or corners of file blanks before and after the first or *over-cut* is made, to prevent weakness of teeth and their liability to break off when used.

*Shouldering file.*—A flat safe-edged file, whose narrower sides are parallel and inclined. When made of large size and right and left they are sometimes called parallel V-files. The small sizes are used by watch-makers.

*Single-cut file.*—A file having but a single series or course of teeth—a *float;* so called in contradistinction to the *double-cut* file, which has two courses or series of teeth crossing each other. The horizontal obliquity of the teeth relatively to the central line of double-cut files is about 55°, but in *single-cut* files the inclination is much less, and in some *floats* the teeth are square across the face of the file.

*Slab file.*—Misnomer for the half-round files; so called from resemblance to the "slab" or outside piece sawn from a log.

*Slim hand-saw taper file.*—A file lighter and longer than the ordinary hand-saw file. Allows a greater sweep or stroke in filing.

*Slitting file.*—A file with two acute and two obtuse edges and parallel sides. Its cross-section is a rhomb whose longer diagonal has, say, three times the length of the shorter one. A lozenge-shaped file.

*Slotting file.*—A file made from pillar sections with sides and edges *equaling.* It is double-cut and principally used for filing grooves for cotters, keys, or wedges.

*Smooth file.*—A finishing file, whose teeth are of a grade of coarseness between the *second-cut* and the *dead-smooth.* The angle of the chisel in cutting is about 5° from the perpendicular. For number of cuts to the inch, see table.

*Square blunt file.*—A file from 10 to 20 inches in length, cut double—generally bastard. Used for finishing and enlarging mortises in railroad shops and in ship-yards. May have one or two safe sides.

*Square equaling file.*—A file like square blunt except curved or *bellied* on sides; used for finishing key-ways, splines, &c., doing the nicer work. All made double-cut.

*Square file.*—A file which is square in its transverse section. It is usually taper, and has one safe side. It is used as an *entering* file in starting key-ways and grooves for splines, cotters, and wedges. Very generally used in almost all branches of mechanical industry. Lengths of square taper files usually range from 3 to 16 inches.

*Steel.*—A round rod of hardened steel, used for sharpening knives. The surface is covered with either circular, diagonal, or longitudinal striated lines.

*Superfine file.*—A dead-smooth file, which see.

*Swing-wheel file* (*watch-making*).—A file for dressing out the openings in the steel disk from which the balance-wheel is made. A *cross file.*

*Taper cotter.*—See *Cotter taper.*

*Taper file.*—A file which is rectangular in section, and whose thickness and width gradually decrease toward the point. The faces are not quite flat in the direction of their length, but are somewhat rounded: technically known as *bellied.*

A flat file without a belly is known as a *parallel* file. The term taper may be applied either to the sides or edges, or to both.

*Taper-full file.*—See *Full taper.*

*Three-square blunts.*—A small file from 3 to 6 inches in length—for machine-shop work.

*Three-square file.*—The ordinary tapering, hand-saw file of triangular cross-section. A misnomer. In this file the edges are not cut.

*Top-cut.*—Same as *up-cut*, which see.

*Topper—Topper file.*—An equilateral *single-cut* file, or *float*, used by comb-makers.

*Triangular file.*—The ordinary tapering, hand-saw file of triangular cross-section. Also known as a *three-square* file.

*Tumbler file.*—A file with convex sides, formerly used for tumblers in gun-locks; double-cut.

*Turn file.*—A burnisher, used in throwing up slight burs on the edges of the comb-maker's files, the teeth of which are originally made by the file and not by the chisel. Used by workers on horn, tortoise-shell, iron, and bone.

*Union-cut files.*—Double-cut files having a *fine over-cut*, and a quite coarse or *open up-cut;* the horizontal obliquity of the two cuts is the same as in the ordinary double-cut, the principal peculiarity being that any tendency to glide is always in the opposite direction to that of the ordinary double-cut, owing to the open up-cut. The file should also free itself more readily from the filings.

*Up-cut.*—The second course or series of teeth, which crosses the first, and in most double-cuts is finer and has a horizontal obliquity varying from 5° to 15°; sometimes called cross-cut.

*Valve file.*—A file with two acute and two obtuse angles; used in filing valve and *key-ways*, grooves for pins, feathers, splines, &c.

*Verge file (watch-making).*—A fine file with one *safe* side, formerly used in working on the verge of the old vertical escapement.

*Warding blunt—(Nicholson.)*—A fine-cut file, having same section as warding file, and has similar uses; called *equaling file* by the English.

*Warding file.*—A flat file, having a constant thickness, and only cut upon the edges; used in filing the ward-notches in keys. These files are considerably used by jewelers and machinists; range from 3 to 8 inches in length—by half-inches below 6-inch; fine double-cut, edges tapered.

*Warding round-edge file, or drill file.*—A blunt file, made from warding sections, cut on edges only, which are quite rounding, generally second-cut, single; used for filing bottom of slots and filing small twist-drills, &c.

*Watchmaker's files.*—These files are of various kinds and grades as to size, degree of taper, coarseness of cut, shape, safe-edged, or otherwise.

Among these special files are a few which are not given above, viz:

Endless-screw file.
Barrel-hole file.
Clock-pinion file.
Clock-slitting file.
Flat dovetail file.
French pivot file.
Watch-pinion file.
Watch-slitting file.

## II.—TRIGLOT SYNONOMY.

[NOTE.—Under the head of "Triglot Synonymy" the various terms in the English, French, and German languages relating to filing, file-cutting, files, and rasps have been brought together for convenience of reference.]

### ENGLISH—GERMAN—FRENCH.

| English. | German. | French. |
|---|---|---|
| File, *s.* | Die Feile. | Lime, *f.* |
| Adjusting file. (Mint.) | Die Justirfeile. | La lime à ajuster.<br>L'écouane, *f.*<br>L'écouenne, *f.* |
| Angular file. (Locksm.) | Die Eckfeile. | La lime angulaire. |
| Arm file, *s.*, Rubber, *s.* (Locksm.) | Die Armfeile.<br>Die grobe vierkantige Feile. | Le carreau.<br>La lime à bras. |
| Balance-wheel file or Swing-wheel file. (Watchm.) | Die Steigradfeile. | La lime à roue de rencontre. |
| Bastard-cut, *s.*, of a file. (Filec.) | Der Mittelhieb.<br>Der Bastardhieb. | La moyenne taille.<br>La taille bâtarde. |
| Bastard-file. (Locksm.) | Die Bastardfeile.<br>Die Vorfeile. | La lime bâtarde. |
| Bastard file. (Watchm.) | Die Uhrmacherbastardfeile. | La crapone. |
| Bent rasp, *s.*, Crooked file, or Cobler, *s.* (Gunm.) | Die Krückraspel. | L'écouenne, *f.*<br>L'écouane, *f.*<br>L'éco[u]ine, *f.*, courbée du monteur. |
| Bow file, *s.*, Riffler, *s.* (Techn.) | Die Bogenfeile.<br>Die Riffelfeile. | La lime à archet.<br>Le rifloir.<br>Le riflard. |
| Bridle file, *s.* | Die Studelfeile. | La lime à cramponnet. |
| Burnisher, *s.*, Polishing file, *s.* (Goldsm.) | Die Polirfeile. | Le burnissoir. |
| To choke up, *v. a.*, the teeth of a file. (Locksm.) | Die Feile verschmieren, verschleimen. | Empâter la lime. |
| Coarse file. (*See* Rough file.) | | |
| Cobbler, *s.* (Armorer's). (*See* Bent rasp. | | |
| Course, *s.*, of file cuts. (Filec.) | Die Hieblage.<br>Der Hieb. | La couche de taille.<br>La taille. |
| First course. | Der Unterhieb.<br>Der Grundhieb. | La première taille. |
| Second course. | Der Kreuzhieb.<br>Der Oberhieb. | La seconde taille. |
| Crooked file. *See* Bent rasp. | | |
| Cross file. | Die Vogelzunge. | La fueille de sauge. |
| Crossing file, Double half-round. (Techn.) | | |
| Cut, *s.*, of a file. (*See* Course of file cuts.) | Der Hieb.<br>Der Feilenhieb. | La taille. |
| Bastard-cut. (*See* Bastard-cut.) | | |
| Rough-cut. | Der grobe Hieb. | La grosse taille. |
| Smooth-cut. | Der feine Hieb. | La fine taille.<br>La douce taille. |
| To cut, *v. a.*, files. (Filec.) | Feilen hauen. | Tailler les limes. |
| To cut anew.<br>To cut again.<br>To recut, *v. a*, the files. | Aufhauen. | Retailler. |
| Cutting, *s*, File cutting (action). (Techn.) | Das Feilenhauen.<br>Das Hauen. | La taille. |
| Cutting-block, File-cutting anvil, *s.* (Techn.) | Das Haueisen.<br>Der Hauamboss für feilen. | L'enclume, *f.*, à entailler les limes.<br>Le tas. |
| Double-cut file. (Filec.) | Die zweihiebige Feile. | La lime à taille croisée.<br>La lime taillée à deux. |
| Dovetail file. (Watchm.) | Die Schwalbenschwanzfeile.<br>Die Steigradschieberfeile. | La lime à queue d'aronde. |
| Equaling file. (Watchm.) | Die Zahnfeile.<br>Die Ausstreichfeile. | La lime à égalir. |
| Feather-edged file. (*See* Slitting file.) | | |
| File-cutting, *s.* (*See* Cutting.) | | |
| Fine-toothed file. | Die Mittelfeile. | La lime moyenne. |
| Flat file. (*See* Hand file.) | | |
| Float, *s.* (Filec.) (*See* Single-cut file.) | | |
| Hand file, *s.*, Flat file, *s.* | Die Handfeile. | La lime plate. |
| Safe edge, *s.* (Filec.) | Die flache Feile. | La plate large. |
| *For* Taper hand file, *see* Taper flat file.) | Die Ansaztfeile. | La plate à main. |
| Half-round file. (Locksm.) | Die halbrunde Feile. | La demi-ronde. |
| Key file, *s.*, Blade file, *s.* | Die Spaltfeile. | La lime à clef.<br>La lime fendante. |
| Knife file, *s.* (Filec.) | Die Messerfeile. | La lime en couteau. |
| Needle file, *s.* (Techn.) | Die Nadelfeile. | La lime à aiguille.<br>La lime d'aiguilles. |

## II.—TRIGLOT SYNONYMY—Continued.

### ENGLISH—GERMAN—FRENCH.

| English. | German. | French. |
|---|---|---|
| Oval file, *s.* | | La lime à double dos. |
| Parallel file. | Die gleichbreite Feile. | La lime parallèle. |
| Pinion file. (Watchm.) | Die Triebfeile. | La lime à pignon. |
| Pivot file. (Watchm.) | Die Zapfenfeile. | La lime à pivots. |
| Planchet file. | Die Schrotfeile. | La lime à ébarber. |
| Polishing file. (Locksm.) | Die Polirfeile. | La carrelette. |
| Polishing file, *s.* (Watchm.)<br>Burnisher, *s.* (Which see.) | Die Polirfeile. | Le burnissoir. |
| Rasp, *s.* (Joiner's.) | Die Nuthenraspel.<br>Der Nuthenreisser. | La ramasse. |
| Crooked rasp. | Die Krummraspel. | L'égobine, *f.* |
| Farrier's or Smith's rasp. | Die Hufraspel. | La râpe. |
| Fine rasp, Grater file. (Joiner's.) | Die Feinraspel. | L'écouanette, *f.*, à bois. |
| Rasp file, *s.* | Die Raspelfeile (Raspel mit Feilenhieb auf einer Seite.) | La râpe anglaise. |
| Rat-tail file. (Techn.) | Der Rattenschwanz. | La queue de rat. |
| Riffler, *s.* (Filec.) | Die Riffelfeile. | Le rifloir. |
| Rifler, *s.* | Die Raumfeile. | Le riflard. |
| Rubber, *s.*, Arm file, *s.* (Techn.) | Die Armfeile. | Le carreau.<br>La lime à bras. |
| Rubber, *s.* (for slide-valve faces). (Mach.) | Die Schieberfeile. | La lime carrée pour égayer les joues du tiroir. |
| Rubber, *s.* (Goldsm., silversm.) | Die Liegefeile. | La lime très-large et plate qu'on met sur la table et sur laquelle on fait passer l'objet qu'on veut limer. |
| Rough cut, *s.* (of a file). (Filec.) | Der grobe Hieb. | La grosse taille. |
| Rough file, coarse file. (Techn.) | Die Grobfeile. | La lime grosse.<br>La lime rude. |
| Rough file, packed in straw. (Techn.) | Die Strohfeile. | La lime d'Allemagne.<br>La lime en paille. |
| Round file. (Techn.) | Die runde Feile. | La lime ronde. |
| Round-off file. (Watchm.) | Die Wälzfeile. | La lime á arrondir. |
| Safe-edge, *s.* (*See* Hand file.) | | |
| Saw file, for sharpening saws. (Techn.) | Die Sägefeile. | La lime á scies. |
| Screw-head file. (Techn.) *See* Slitting file.) | | |
| Second-cut file. (Lochsm.) | Die Halbschlichtfeile. | La lime demi-douce. |
| Sharp file. | Die Stossfeile. | La lime á bouter. |
| Single-cut file, Float, *s.* (Filec.) | Die einhiebige Feile. | La lime a taille simple.<br>La lime taillée sans croisement. |
| Slitting file, Feather-edged file, Screw-head file. (Mach., Locksm.) | Die Einstrichfeile.<br>Die Schraubenkopffeile. | Le lozange.<br>Le losange.<br>La lime á dossière. |
| Small file. | Die Handfeile.<br>Die kleine Feile. | La lime á main.<br>La limatule. |
| Smooth-cut. (Filec.) | Der feine Hieb. | La fine taille.<br>La douce taille. |
| Smooth file. (Techn.) | Die Schlichtfeile. | La lime douce. |
| Square file. | Die kleine vierkantige Feile. | Le carrelet.<br>Le quatre quarts. |
| Superfine file, Dead-smooth-file.<br>(Techn.) | Die Feinschlichtfeile.<br>Die Schlichtschlichtfeile. | La lime superfine. |
| Swing-wheel file. (Watchm.) (*See* Balance-wheel file.) | | |
| Taper file. *s.* (Techn.) | Die Spitzfeile.<br>Die Spitze Feile. | La lime pointue. |
| Taper flat file. } (Techn.)<br>Taper hand file. } | Die Spitzflache Feile.<br>Die flache Spitzfeile. | La lime plate pointue. |
| Triangular file. } (Techn.)<br>Three-square file. } | Die Dreieckige Feile.<br>Die dreikantige Feile. | Le tiers-point.<br>La lime triangulaire.<br>Le trois-quarts.<br>Latrois-carrés. |
| To file, *v. a.* (Techn.) | Feilen, abfeilen, befeilen. | Limer. |
| To file across. | Querfeilen.<br>Überzwerchfeilen. | Limer en travers.<br>Croiser les traits en limant. |
| To file by hand. | Im Feilklöbchen feilen. | Limer á main. |
| To file lengthwise or lengthways. | Längsfeilen.<br>Der Länge nach feilen. | Limer en long. |
| To file off, *v. a.* (Techn.) | Abfeilen. | Enlever avec la lime. |
| To file over, *v. a.* | Überfeilen. | Passer la lime sur—.<br>Promener la lime sur —. |
| To file roughly. (Cutl.) | Aus dem Groben feilen. | Ébaucher. |
| File-cut. (*See* Cut of a file.) | | |
| File-cutter, *s.* | Der Feilhauer. | Le tailleur de limes. |
| File-cutter's chisel, *s.* | Der Feilenmeissel. | L'étoile, *f.*, du tailleur de limes. |

## II.—TRIGLOT SYNONYMY—Continued.

### ENGLISH—GERMAN—FRENCH.

| English. | German. | French. |
|---|---|---|
| File-cutting anvil, *s.* (*See* Cutting block.) | | |
| File-dust, *s.* } (Techn.)<br>Filings, *s. pl.* } | Die Feilspäne, *m. pl.*<br>Das Feilicht.<br>Der Feilstaub. | La limaille.<br>La limature. |
| Iron file-dust. } (Locksm., etc.)<br>Iron filings. } | Die Eisenfeilspäne, *m. pl.* | Les limailles, *f. pl.*, de fer. |
| File-handle. (Techn.) | Das Feilenheft. | Le manche de lime. |
| File hardening. (Techn.) | Die Feilenhärtung. | La trempe des limes. |
| File-stroke. | Der Feilenstrich.<br>Der Feilenzug. | Le coup de lime.<br>Le trait de lime. |
| File tooth, *s.* | Der Feilenzahn.<br>Die Hiebzanke, der Hieb. | La dent de taille. |
| Filing, *s.* (Locksm., etc.) | Das Feilen. | La limure. |
| Filing-block. } (Techn.)<br>Filing-board. } (Pinm.) | Das Feilholz.<br>Das Spitzstöckel. | Le bois á limer, l'estibois, *m.*, entibois, *m.*, étibois, *m.*, étibau, *m.*, étibot, *m.* |
| Filing machine. (Mach.) | Die Feilmaschine. | La limeuse.<br>La machine á limer. |

### FRENCH—GERMAN—ENGLISH.

| French. | German. | English. |
|---|---|---|
| Affiler, Affûter, *v. a.*, un outil. | Schärfen, abziehen. | To sharpen. |
| Affûter, limer les dents d'une scie. | Die Zähne schärfen. | To sharpen the teeth (of a saw). |
| Brunissoir, *m.* | Die Polirfeile. | Burnisher, polishing file. |
| Carreau, *m.*, Lime, *f.*, à bras. | Die Armfeile. | Arm file, rubber. |
| Carrelet, *m.*, (petite lime carrée). | Die kleine viereckige Feile. | Square file. |
| Carrelet plat. | Die dickflache Feile. | Cotter file. |
| Carrelette, *f.* | Die Polirfeile. | Polishing file. |
| Coup, *m.*, de lime. | Der Feilenstrich, Feilenzug. | File-stroke. |
| Crapone, *f.* (Horl.) | Die Uhrmacher-Bastardfeile. | Bastard file for watchmakers. |
| Croiser, *v. a.*, les traits en limant. | Ueber Kreuz feilen. | To cross the strokes (in filing). |
| Demi-ronde, *f.* (lime plate d'un coté et ronde de l'autre. | Die halbrunde Feile. | Half-round file. |
| Dent, *f.*, d'une lime. | Der Feilenzahn. | Tooth (file) [*pl.* teeth.] |
| Ébauchage, *m.*, de la lime. | Das Grobfeilen der Klinge. | Rough filing. |
| Ébaucher, *v. a.* (Cout.) | Aus dem Groben feilen. | To file roughly. |
| Écouane, Écouenne, Écoine, *f.* | Die Raspel. | Rasp file. |
| Écouane plate pour ajuster les flans. | Die Justirfeile.<br>Die Münzfeile.<br>Die Schrötlingsfeile.<br>Die Beschrotfeile. | Adjusting file.<br>Planchet file. |
| Écouane à bois, Écouanette. | Die Feinraspel. | Fine rasp, grater file. |
| Écouane courbée du monteur. | Die Krückraspel. | Bent rasp, crooked file. |
| Égobine, *f.*, espèce de râpe courbe. | Die krumme Raspel. | Crooked rasp. |
| Empâter, *v. a.*, la lime, dit d'un métal, etc. | Verschmieren.<br>Verschleimen. | To choke up the teeth of a file. |
| Enclume, *f.*, à entailler les limes. | Das Haueisen.<br>Der Hauamboss. | Cutting-block.<br>File-cutting anvil. |
| Enduit, *m.*, pour les limes [avant la trempe]. | Die Härte. | Hardening composition. |
| Enduire les limes. | Die Feilen härten. | To harden the files. |
| Enlever, *v. a.*, avec la lime. (Tech.) | Abfeilen. | To file off. |
| Étoile, *f.*, du tailleur de limes. | Der Feilenmeissel. | Filecutter's chisel. |
| Feuille, *f.*, de sauge, une lime ovale et pointue. | Die Vogelzunge. | Cross file, crossing file, double half-round file. |
| Limaille, *f.* }<br>Limature, *f.* } | Die Feilspäne, *pl.* }<br>Das Feilicht, der Feilstaub. } | Filings, *pl.* }<br>File-dust. } |
| Limailles, *pl.*, de fer. | Die Eisenfeilspäne. | Iron-sand (or steel-dust). |
| Limatule, *f.* Syn. de Lime, *f.*, à main. | | |
| Lime, *f.* (Tech.) | Die Feile. | File. |
| Lime à aiguille. } (Tech.)<br>Lime d'aiguilles. } | Die Nadel-Feile. | Needle file. |
| Lime à ajuster. | Die Justirfeile. | Adjusting file. |
| Lime d'Allemagne. }<br>Lime, *f.*, en paille. } | Die Strohfeile. | The straw-packed file. |
| Lime à archet, le rifloir. | Die Bogenfeile.<br>Die Riffelfeile. | Bow file, rifler. |
| Lime à arrondir. (Horl.) | Die Wälzfeile. | Round-off file. |
| Lime bâtarde. } (Tech.)<br>Lime à moyenne taille. } | Die Bastardfeile, Vorfeile.<br>Die Feile mit Mittelhieb. | Bastard file. |
| Lime à bouter. | Die Stossfeile. | Sharp file. |

## II.—TRIGLOT SYNONYMY—Continued.

### FRENCH—GERMAN—ENGLISH.

| French. | German. | English. |
|---|---|---|
| Lime à bras, carreau, *m.* | Die Armfeile. | Arm file, rubber. |
| Lime carrée. | Die viereckige Feile. | Square file. |
| Lime carrée, pour égayer les joues des tiroirs. (Machines à vapeur.) | Die Schieberfeile. | Rubber (for slide valve faces). |
| Lime à charnière. (Tech. Horl.) | Die Charnierfeile. | Joint file. |
| | Die Charnierplatzfeile. | Round-edge joint file. |
| Lime à clef. (Serrur.) | Die Spaltfeile. | Key file. |
| Lime fendante. | | Blade file. |
| Lime à couteau. (Serrur.) | Die Messerfeile. | Knife file. |
| Lime à dossierre. | Die Schneidefeile. | Hack file. |
| Lime à cramponnet. (Serrur.) | Die Studelfeile. | Bridle file. |
| Lime demi-douce. (Tech.) | Die Halb-Schlichtfeile. | Second-cut file. |
| Lime demi-ronde. (*Voyez* Demi-ronde.) | | |
| Lime à deux trenchants. | Die zweischneidige Feile. | Double-cutting file. |
| Lime à dossières. (Serr. Mach.) | Die Einstreichsäge. | Screw-head saw file. |
| Lime à dossier. | Die Einstreichfeile. | Hack-saw file. |
| Losange, *m.* | Die Schraubenkopffeile. | |
| Lozange, *m.* | | |
| [Lime à fendre les vis.] | | |
| Lime douce. | Die Schlichtfeile. | The smooth file. |
| | Die Abziehfeile. | |
| Lime à ébarber. | Die Schrotfeile. | Planchet file. |
| Lime à efflanquer. (Horl.) | Die Flankirfeile. | Thinning file. |
| Lime à égalir. (Horl.) | Die Zahnfeile. | Equaling file. |
| [Lime servant à polir les espaces des roues d'une montre]. | Die Ausstreichfeile. | |
| Lime d'éntree. (Tech.) | Die schmale Spitzfeile. | Entering file. |
| | Die Lochfeile. | |
| Lime d'étain. | Die Zinnfeile. | Tin file. |
| Lime à feuilles de sauge. | Die Riffelfeile. | Riffler. |
| Lime grosse, Lime rude. | Die Grobfeile. | Rough or coarse file. |
| Lime d'horloger. | Die Uhrmacherfeile. | Clockmaker's file, watchmaker's file. |
| Lime à main. | Die Handfeile. | Small file. |
| La Limatule. | Die kleine Feile. | |
| Lime mordante. | Die Raspel. | Rasp. (*Voyez* Râpe.) |
| Lime moyenne. | Die Mittelfeile. | Fine-toothed file. |
| Lime en paille, Lime d'Allemagne. | Die Strohfeile. | Straw-packed rough file. (*Voyez* Lime grosse.) |
| Lime au paquet. (Tech.) | Die Bundfeile. | Bundle file. |
| Lime parallèle. | Die gleichbreite Feile. | Parallel file. |
| Lime à pignon. (Horl.) | Die Triebfeile. | Pinion file. |
| Lime à pilier. (Tech.) | Die dickflache Feile. | Pillar file. |
| Lime à pivots. (Horl.) | Die Zapfenfeile. | Pivot file. |
| Lime plate. (Tech.) | Die flache Feile. | Hand file. |
| La plate large. | Die Ansatzfeile. | Flat file. |
| La plate à main. | | Safe-edge. |
| Lime plate pointue. (Tech.) | Die spitze Feile. | Taper file. |
| | Die Spitzfeile. | |
| Lime à queue d'aronde. (Horl.) | Die Schwalbenschwanzfeile. | Dovetail file. |
| | Die Steigradschieberfeile. | |
| Lime ronde. | Die runde Feile. | Round file. |
| Petite lime ronde, Queue de fond de rat. | Der Rattenschwanz. | Rat-tail file. |
| Lime à roue de rencontre. (Horl.) | Die Steigradfeile. | Balance-wheel file, swing-wheel file. |
| Lime à scies. (Tech.) | Die Sägefeile. | Saw file. |
| Lime triangulaire. | | |
| Lime en carrelet. | | |
| Lime superfine. (Tech.) | Die Feinschlichtfeile. | Superfine file. |
| | Die Schlichtschlichtfeile. | Dead-smooth file. |
| Lime à taille croisée. | Die zweihiebige Feile. | Double-cut file. |
| Lime à taille double. | | |
| Lime à contre-taille. | | |
| Lime taillée à deux. | | |
| Lime à taille simple. (Tech.) | Die einhiebige Feile. | Single-cut file, or float. |
| Lime taillée sans croisement. | | |
| Lime triangulaire. | Die dreieckige Feile. | The three-square file. |
| Le tierspoint, *m.* | | Triangular file. |
| Limer, *v. a.* (Tech.) | Feilen, abfeilen, befeilen. | To file. |
| Limer, *v. a.* Affûter les dents d'une scie. | Die Zähne schärfen. | To sharpen the teeth (of a saw). |
| Limer en long. | Der Länge nach feilen. Längs feilen. | To file lengthwise. Lengthways. |
| Limer à la main. | Im Feilklöbchen feilen. | To file by hand, in a hand-vise. |

## II.—TRIGLOT SYNONYMY—Continued.

### FRENCH—GERMAN—ENGLISH.

| French. | German. | English. |
|---|---|---|
| Limer en travers. | Querfeilen.<br>Ueberzwerch feilen. | To file across. |
| Limeur, *m.*, Étau, *m.*, limeur. | Der Feilkolben. | Filing-vise. |
| Limeuse, *f.* (Tech.)<br>Machine à limer. | Die Feilmaschine. | Filing-machine, shaving-machine. |
| Limure, *f.* | Das Feilen, die Feilung. | Filing. |
| Losange, Lozange, *m.* (*Voyez* Lime à dossière.) | | |
| Manche, *m.*, de lime. | Das Feilenheft. | File-handle. |
| Passer, *v. a.*, promener, *v. a.*, la lime sur—. | Ueberfeilen. | To file over. |
| Quatre-quart, *m.* (Serrur.)<br>Carrelet, *m.* | Die kleine viereckige Feile. | Little square file. |
| Ramasse, *f.* | Die Nuthenraspel.<br>Der Nuthenweiter. | Rasp for widening grooves. |
| Râpe, *f.* (Tech.) | Die Raspel. | Rasp. |
| Râpe, *f.*, à bois. (Tourn.) | Die Holzraspel. | Wood-rasp. |
| Râpe, *f.*, à sabot. | Die Hufraspel. | Farrier's or shoeing-smith's rasp. |
| Râpe à sucre. | Die Reibemaschine. | Sugar-rasp. |
| Retailler, *v. a.*, une lime. | Aufhauen. | To cut anew, to cut again, to re-cut a file. |
| Riflard, *m.* (Tech.)<br>Rifloir, *m.* | Die Riffelfeile.<br>Die Raumfeile. | Riffler, rifler. |
| Taillage, *m.*, des limes. (Lim.) | Das Feilenhauen, Hauen. | Cutting (files). |
| Taille, *f.*, d'une lime. (Lim.) | Der Hieb, der Feilenhieb. | Cut (of files). |
| Fine taille. (Tech.)<br>Douce taille. | Der feine Hieb. | Smooth cut. |
| Grosse taille. | Der grobe Hieb. | Rough cut. |
| Moyenne taille. (Tech.)<br>Taille bâtarde. | Der Mittelhieb.<br>Der Bastardhieb. | Bastard cut. |
| Première taille. | Der Unterhieb.<br>Der Grundhieb. | First course (of cuts). |
| Seconde taille. | Der Kreuzhieb.<br>Der Oberhieb. | Second course (of cuts). |
| Tailler, *v. a.*, les limes. | | To cut files. |
| Tailleur de limes. (Lim.) | Der Feilenhauer. | Filecutter. |
| Tas, *m.* | Der Hauamboss. | Anvil for cutting files. |
| Tiers-point, *m.* (*Voyez* Lime triangulaire.) | | |
| Trait, *m.*, de lime. | Der Feilstrich. | File-stroke. |
| Trempe, *f.*, des limes. | Die Feilenhärtung. | File-hardening. |

### GERMAN—ENGLISH—FRENCH.

| German. | English. | French. |
|---|---|---|
| Feile, *f.* (Techn.) | File. | La lime. |
| Bastardfeile. (Techn.)<br>Vorfeile.<br>Feile mit Mittelheib. | Bastard file. | La lime bâtarde. |
| Bogenfeile. (Techn.)<br>(Riffelfeile.) | Bow file (rifler). | La lime à archet.<br>(Rifloir, *m.*, riflard, *m.*) |
| Bundfeile. (Techn.) | Bundle file. | La lime au paquet. |
| Dickflache feile. (Techn.) | Cotter file (pillar file). | Le carrelet plat (la lime à pilier.) |
| Dreieckige feile. (Techn.) | Three-square file.<br>Triangular file. | La lime triangulaire.<br>Le tiers-point.<br>Le trois-quarts.<br>Le trois-carrés. |
| Einhiebige feile. (Techn.) | Single-cut file or float. | Lime, *f.*, à taille simple. |
| Zweihiebige feile. | Double-cut file. | Lime, *f.*, à taille croisée.<br>Lime, *f.*, à taille double.<br>Lime, *f.*, à contre-taille.<br>Lime, *f.*, à taille à deux. |
| Einstreichfeile.<br>Schraubenkopffeile.<br>Einstreichsäge.<br>(Masch., Schloss.) | Slitting file.<br>Feather-edged file.<br>Screw-head file.<br>(Screw-head-saw, hack-saw file.) | Le losange ou lozange.<br>(La lime à dossières ou à dossier.) |
| Feinschlichtfeile.<br>Schlichtschlichtfeile. | Superfine file.<br>Dead-smooth file. | La lime superfine. |
| Flache feile. (Techn.) | Hand file, flat file. | La lime plate, la plate large. |
| Ansatzfeile. | Safe-edge. | La plate à main. |
| Flankirfeile. (Uhrm.) | Thinning file. | La lime à efflanquer. |
| Gleichbreite feile. (Techn.) | Parallel file. | La lime paralèlle. |
| Grobe feile. (Techn.) | Rough or coarse file. | La lime grosse, la lime rude. |
| Halbschlichtfeile. (Techn.) | Second-cut file. | La lime demi-douce. |
| Handfeile. (Techn.)<br>Kleine feile. | Small file. | La lime à main, la limatule. |

## II.—TRIGLOT SYNONYMY—Continued.

### GERMAN—ENGLISH—FRENCH.

| German. | English. | French. |
|---|---|---|
| Justirfeile. | Adjusting file. | La lime à ajuster. |
| Messerfeile. (Schloss.) | Knife file. | La lime en couteau. |
| (Schneidefeile.) | (Hack file.) | (La lime à dossière.) |
| Mittelfeile. (Techn.) | Fine-toothed file. | La lime moyenne. |
| Nadelfeile. (Nadl., Techn.) | Needle file. | La lime à aiguille.<br>La lime d'aiguilles. |
| Raspel, *f.* (Techn.) | Rasp. | La râpe (la lime mordante). |
| Rattenschwanz, *m.* (Techn.) | Rat-tail file. | La queue de rat, la petite lime ronde. |
| Runde feile. | Round file. | La lime ronde. |
| Riffelfeile. (Büchsenm.) | Riffler. | Le rifloir, le riflard. |
| Sägefeile. (Techn.) | Saw file. | La lime à scies, la lime triangulaire, la lime à carrelet. |
| Scharnierfeile. } (Techn.) | Joint file. | La lime à charnière. |
| Scharnierplatzfeile. } (Uhrm.) | Round-edge joint file. | |
| Schieberfeile. (Dampfm.) | Rubber for slide-valve faces. | La lime carrée pour égayer les joues du tiroir. |
| Schlichtfeile. } (Techn.)<br>Abziehfeile. } | Smooth file. | La lime douce. |
| Schrotfeile. (Techn.) | Planchet file. | La lime à ébarber. |
| Schwalbenschwanzfeile. } (Uhrm.)<br>Steigradschieberfeile. } | Dovetail file. | La lime à queue d'aronde. |
| Spaltfeile. (Schloss.) | Key file, blade file. | La lime à clef, lime fendante. |
| Spitzfeile. } (Techn.)<br>Spitze feile. } | Taper file. | La lime pointue. |
| Schmale Spitzfeile. }<br>Lochfeile. } | Entering file. | La lime d'entrée. |
| Spitzflache feile. (Techn.) | Taper flat file, taper-hand file. | La lime plate pointue. |
| Stossfeile. (Techn.) | Sharp file. | La lime à bouter. |
| Strohfeile. (Techn.) | Rough file. | La lime en paille, d'Allemagne. |
| Studelfeile. (Schloss.) | Bridle file. | La lime à cramponnet. |
| Triebfeile. (Uhrm.) | Pinion file. | La lime à pignon. |
| Uhrmacherfeile. | Clockmaker's file, watchmaker's file. | La lime d'horloger. |
| Viereckige feile. (Techn.) | Square file. | La lime carrée. |
| *Grobe viereckige* oder } (Techn.)<br>*vierkantige feile.* }<br>*Armfeile.* } | { Arm file.<br>{ Rubber. | { Le carreau.<br>{ La lime à bras. |
| Kleine viereckige oder vierkantige feile. | Square file (small). | Le carrelet, le quartre-quarts, la lime carrée. |
| Vogelzunge, *f.* | Cross file, crossing file, double half-round. | La feuille-de-sauge. |
| Zahnfeile. } (Uhrm.)<br>Ausstreichfeile. } | Equaling file. | La lime à égalir. |
| Zapfenfeile. (Uhrm.) | Pivot file. | La lime à pivots. |
| Zweischneidige Feile. | Double-cutting file. | La lime à deux tranchants. |
| Feilen härten, *v. a.* | To harden files. | Tremper des limes. |
| Feilen hauen, *v. a.* | To cut the files. | Tailler les limes. |
| Ueberfeilen, *v. a.* | To file over. | Passer, promener la lime sur—. |
| Feilen, Befeilen, Abfeilen, *v. a.* | To file. | Limer. |
| Feilen, der Länge nach, Längsfeilen. | To file lengthwise or lengthways. | Limer en long. |
| Aus dem Groben feilen. | To file roughly. | Ébaucher. |
| Im Feilklöbchen feilen. | To file by hand. | Limer à main. |
| Querfeilen. } | To file across. | Limer en travers. |
| Ueberzwerch feilen. } | To cross the strokes in filing. | Croiser les traits en limant. |
| Die Zähne schärfen, *v. a.* | To sharpen the teeth (of a saw). | Limer, affûter les dents. |
| Mit der Riffelfeile bearbeiten. (Vergold.) | To work with the riffler. | Rifler. |
| Feilen, *n.* (Techn.) | Filing. | La limure. |
| Feilenhärtung, *f.* (Techn.) | File-hardening. | La trempe des limes. |
| Feilenhauen, *n.*, Hauen., *n.* | Cutting (files). | La taille (limes). |
| Feilenhauer, *m.* | Filecutter. | Tailleur, *m.*, de limes. |
| Feilenheft, *n.* | File handle. | Le manche de lime. |
| Feilenhieb, *m.*, Hieb, *m.* | Cut (of files). | La taille. |
| Feilenmeissel, *m.* | Filecutter's chisel. | L'étoile, *f.*, du tailleur de limes. |
| Feilenstrich, *m.* } (*Sieh* Feilstrich.)<br>Feilenzug, *m* } | | |
| Feilholz, *n.* } (Techn.)<br>Feilfutter, *n.* } | Filing-block.<br>Filing-board. | Le bois à limer, étibeau, *m.*<br>Étibot, *m.*, estibois, *m.*, entibois, *m.*, étibois, *m.* |
| Feilicht, *n.* (*Sieh* Feilspäne.) | | |
| Feilkloben, *m.* } (Techn.)<br>Handkloben, *m.* } | Vise, hand-vise. | Étau, *m.*, à main, la pince, la tenaille à vis. |
| Feilmaschine, *f.* (Masch.) | { Filing machine.<br>{ Shaping machine. | { La limeuse.<br>{ La machine à limer. |
| Feilspäne, *m. pl.* } (Techn.)<br>Feilicht, *n.* }<br>Feilstaub, *m.* } | File-dust.<br>Filings, *pl.* | La limaille.<br>La limature. |
| Feilstrich, *m.* } (Techn.)<br>Feilenstrich, *m.* }<br>Feilzug, *m.* } | File-stroke. | La trait (ou coup) de lime. |

## III.—LISTS OF STANDARD FILES.

### 1.—BORLOZ'S FILES.

| Kind. | Number. | Lengths. |
|---|---|---|
| Hand | 0 | |
| Hand | 1 | |
| Hand | 2 | |
| Hand | 3 | |
| Hand | 4 | 3, 3½, 4, 4½, 5, and 6 inches for each number. |
| Hand | 5 | |
| Hand | 6 | |
| Hand | 7 | |
| Hand | 8 | |
| Pillar | 0 | |
| Pillar | 1 | |
| Pillar | 2 | |
| Pillar | 3 | |
| Pillar | 4 | 3, 3½, 4, 4½, 5, and 6 inches for each number. |
| Pillar | 5 | |
| Pillar | 6 | |
| Pillar | 7 | |
| Pillar | 8 | |
| Half-round | | |
| Crossing | | |
| Barette | All numbers of each. | 1½, 1¾, 2, 2¾, 3, 3½, 4, 4½, 5, and 6 inches. |
| Cant | | |
| Equaling | | |
| Taper flat | | |
| Barette, cut on three sides | | |
| Knife, single cut | All numbers. | 1½, 1¾, 2, 2¾, 3, 3½, 4, 4½, 5, and 6 inches. |
| Knife double cut | | |
| Three square | | |
| Three square, single cut | | |
| Square | All numbers. | 1½, 1¾, 2, 2¾, 3, 3½, 4, 4½, 5, and 6 inches. |
| Round | | |
| Screw-heads | | 2 and 2¾ inches. |
| Escapement files | | |

### 2.—GROBET'S FILES.

| Kind. | Number. | Lengths. |
|---|---|---|
| Hand | 00 | |
| Hand | 0 | |
| Hand | 1 | |
| Hand | 2 | |
| Hand | 3 | 1¾, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7, 8, 9, and 10 inches. |
| Hand | 4 | |
| Hand | 5 | |
| Hand | 6 | |
| Hand | 7 | 1¾, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7, and 8 inches. |
| Hand | 8 | |
| Pillar, two safe edges | 00 | |
| Pillar, two safe edges | 0 | |
| Pillar, two safe edges | 1 | |
| Pillar, two safe edges | 2 | 1¾, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7, 8, 9, and 10 inches. |
| Pillar, two safe edges | 3 | |
| Pillar, two safe edges | 4 | |
| Pillar, two safe edges | 5 | |
| Pillar, two safe edges | 6 | |
| Pillar, two safe edges | 7 | 1¾, 2, 2½, 3, 3½, 4, 4½, 5, 6, and 7 inches. |
| Pillar, two safe edges | 8 | |
| Pillar, one safe edge | | Narrow or slim are up to 3½ inches in length. ⅛, 3/16, 7/32, and ¼ inch in width; 5 and 6 inch lengths are ¼, 5/16, 11/32, ⅜, 7/16, and ½ inch in width; 7, 8, 9, and 10 inch lengths are from ⅜ to ¾ inch in width. |
| Half-round | All numbers, from 00 to 8. | 1¾, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7, and 8 inches. |
| Equaling | | |
| Barette | | |
| Crossing | | |
| Warding | All numbers, from 00 to 8. | 1¾, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7, and 8 inches. |
| Cant | | |
| Knife | | |
| Barette, cut on three sides | All numbers. | 3½, 4, 4½, and 5 inches. |
| Joint (or drill) | | 3, 3½, 4, 4½, and 5 inches. |
| Round | From 00 to 8. | 1¾, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7, and 8 inches. |
| Round-straight | | 1¾, 2, 2½, 3, 3½, 4, 4½, and 5 inches. |
| Square | From 00 to 8 | 1¾, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7, and 8 inches. |
| Screw-head files | | 1¾, 2, 2½, 3, 3½, 4, and 4½ inches. |
| Three-square | From 00 to 8. | 1¾, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7, 8, 9, and 10 inches. |
| Escapement files | | 1¾ and 2 inches. |

N. B.—No. 00 is about basterd cut, and No. 8 about 400 cuts in one inch. Warding, equaling, or joint files run from No. 8 to No. 28 standard wire-gauge in thickness.

## III.—LISTS OF STANDARD FILES—Continued.

### 3.—PROUTAT'S FILES.

| Kind. | | Number. | Lengths. |
|---|---|---|---|
| Hand—Bastard | | 1 | 2, 3½, 4, 5, 6, 7, 8, 9, 10, 11, and 12 inches. |
| Second cut | | 2 | |
| Smooth | | 3 | |
| Dead-smooth | | 4 | |
| Hand | | 5 | 2, 3½, 4, 5, 6, and 7 inches. |
| Hand | | 6 | |
| Half-round | Bastard | | 2, 3½, 4, 5, 6, 7, 8, 9, 10, 11, and 12 inches. |
| Crossing | | | |
| Knife | | | |
| Screw-head | | | |
| Round-straight | | | |
| Half-round | Second cut | | 2, 3½, 4, 5, 6, 7, 8, 9, 10, 11, and 12 inches. |
| Crossing | | | |
| Knife | | | |
| Screw-head | | | |
| Round-straight | | | |
| Half-round | Smooth | | 2, 3½, 4, 5, 6, 7, 8, 9, 10, 11, and 12 inches. |
| Crossing | | | |
| Knife | | | |
| Screw-head | | | |
| Round-straight | | | |
| Half-round | Dead-smooth | | 2, 3½, 4, 5, 6, 7, 8, 9, 10, 11, and 12 inches. |
| Crossing | | | |
| Knife | | | |
| Screw-head | | | |
| Round-straight | | | |
| Pillar | Either bastard, second cut, smooth, or dead-mooth. | | 2 to 12 inches. |
| Three-square | | | |
| Four-square | | | |
| Round | | | |
| Warding | | | |
| Flat taper | | | |
| Barette | | | |
| Cant | | | |
| Equaling | | | |
| Pit-saw or frame-saw files | | | 5 and 10 inches. |

### 4.—KEARNEY & FOOT'S FILES.

| Name. | Name. | Name. |
|---|---|---|
| Flat. | Round. | Double cut taper-saw. |
| Half-round. | Three-square. | Crossing. |
| Hand. | Mill-saw. | Warding files. |
| Pillar. | Taper saw. | Joint files. |
| Equaling. | Taper-saw, single cut. | Cabinet files. |
| Cotter or pivot. | Slim taper-saw, single cut. | Cabinet rasps. |
| Square. | Band taper-saw, single cut. | Wood rasps. |

*Proportionate lengths and diameters of standard files.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Round and square | ⅛ | 3/16 | ¼ | ⅜ | ½ | ⅝ | ¾ | ⅞ | 1 inch in diameter or thickness. |
| | 3 & 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 inches in length. |

### 5.—NICHOLSON'S INCREMENT-CUT FILES.

*Files in general use.*

| Kind. | Cut. | Length in inches. |
|---|---|---|
| Mill, round, flat, and square | Bastard | 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18. |
| | Second | |
| | Smooth | |
| Hand and half-round | Bastard | 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18. |
| Hand and half-round | Second | |
| Hand and half-round | Smooth | |
| Warding | Bastard | 4, 5, 6, 7, 8, 9, 10, 11, and 12. |
| Warding | Second | |
| Warding | Smooth | |
| Pit-saw | Single | 4, 5, 6, 7, 8, 9, 10, 11, and 12. |
| Round gulleting | | |
| Hook-tooth | Single | 6, 7, 8, 9, 10, 11, and 12. |

## III.—LISTS OF STANDARD FILES—Continued.

### 5.—NICHOLSON'S INCREMENT-CUT FILES—Continued.

*Files in general use*—Continued.

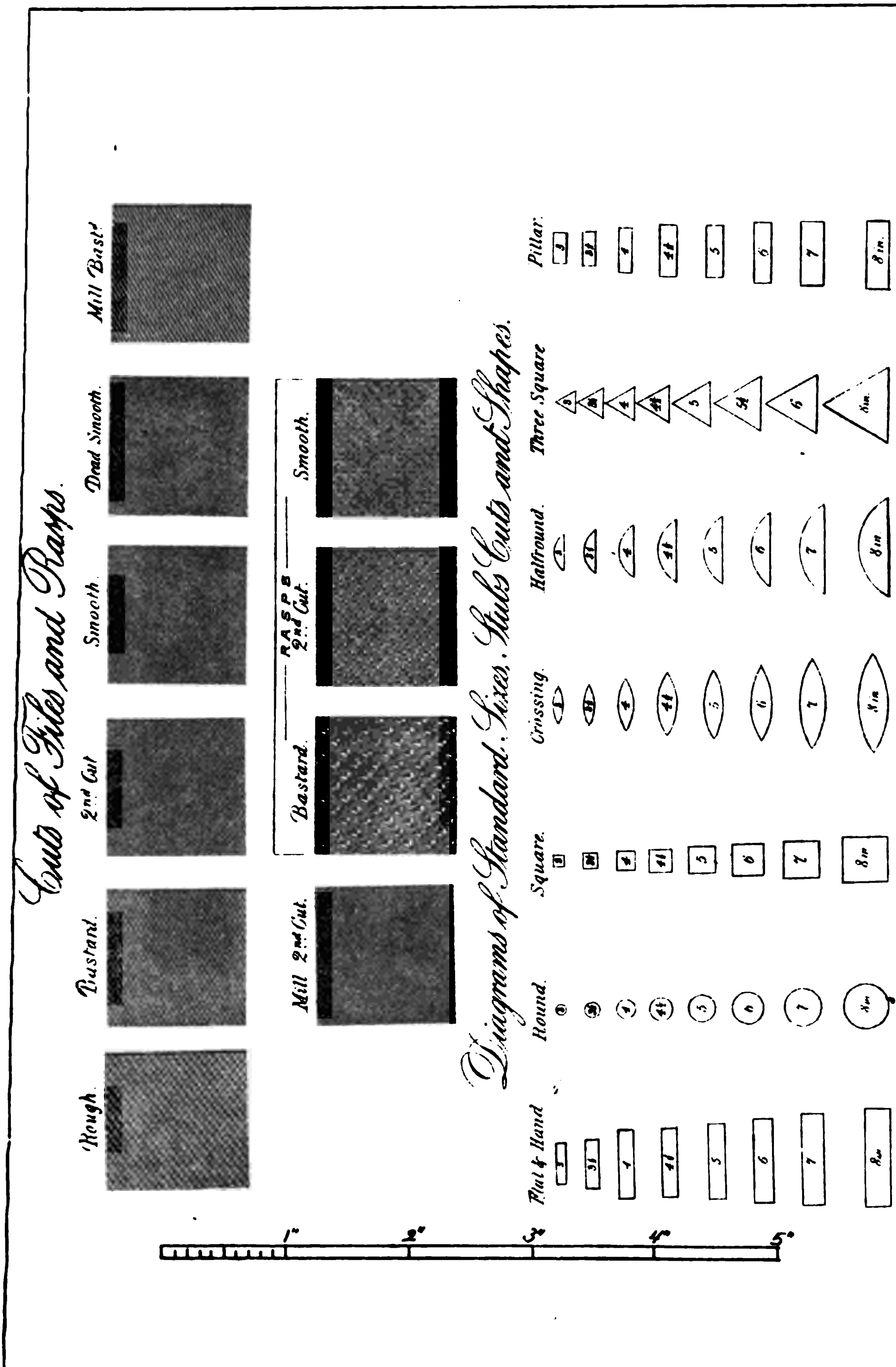
| Kind. | Cut. | Length in inches. |
|---|---|---|
| Reaper | Single | 7, 8, 9, and 10. |
| Machine-mill | | |
| Gang-edger | Single | 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18. |
| Mill-pointing | | |
| Flat, wood | Double | 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18. |
| Half-round, wood | | |
| Cabinet | File or rasp | |
| Flat, wood | Rasp | 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16. |
| Half-round, wood | Rasp | |
| Half-round, shoe | Rasp | 6, 7, 8, 9, 10, 11, and 12. |
| Plain horse (Regular and racer) | Rasp | 10, 11, 12, 13, 14, 15, 16, 17, and 18. |
| Tanged horse (Regular and racer) | Rasp | 10, 11, 12, 13, 14, 15, and 16. |
| Hand-saw taper | Single | 2½, 3, 3½, 4, 4½, 5, 5½, 6, 7, 8, 9, 10, 11, 12, 13, and 14. |
| Hand-saw taper | Double | |
| Hand-saw taper (slim) | Single | 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14. |
| Hand-saw taper (slim) | Double | |
| Lightning | Single | 4, 5, 6, 7, 8, 9, 10, 11, and 12. |
| Band-saw (taper) | Single | 2½, 3, 3½, 4, 4½, 5, 5½, 6, 7, 8, 9, and 10. |
| Gin-saw | Single | |
| Knife | Double | 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18. |
| Double-ender | Single | 7, 8, 9, and 10. |

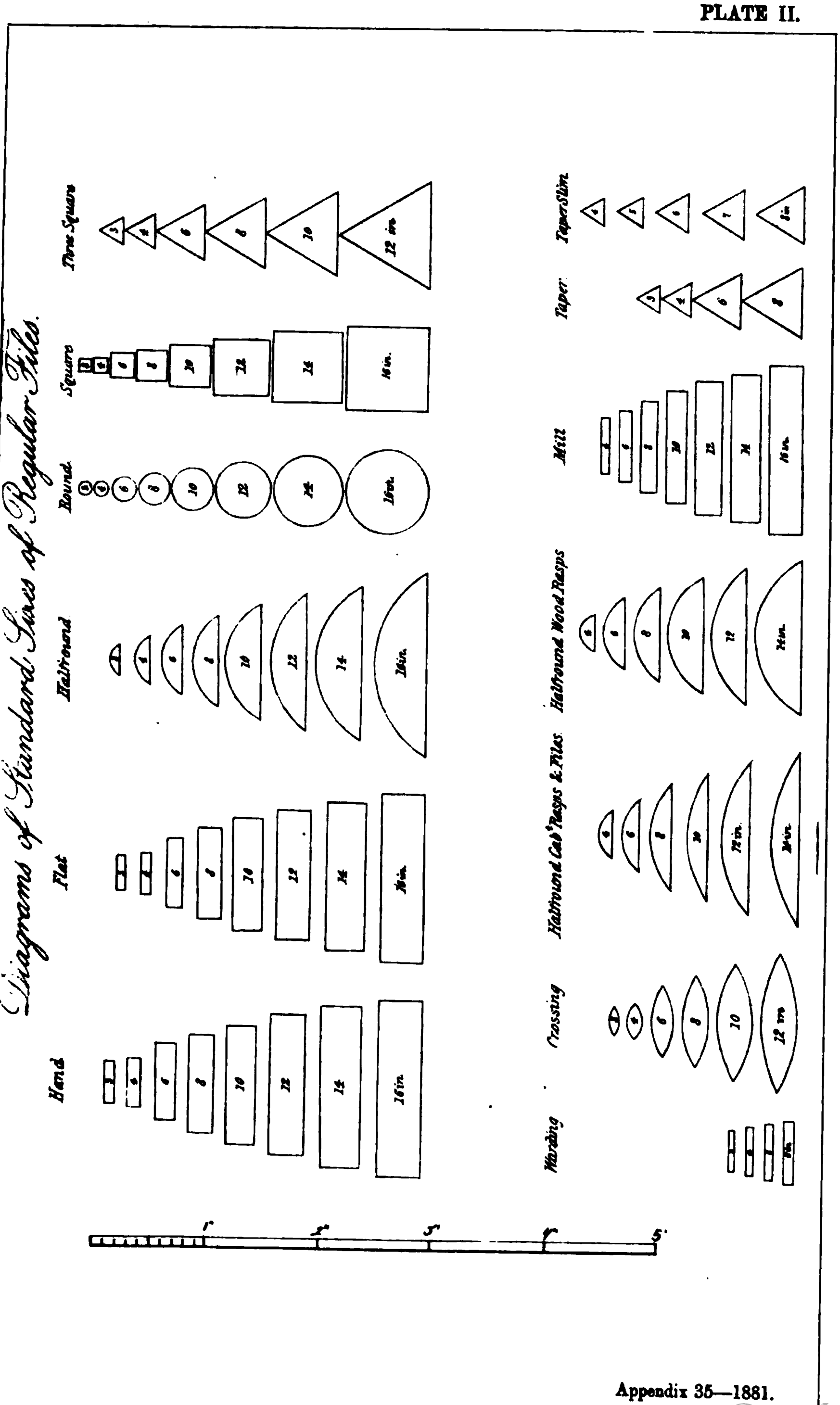
*Files in less common use.*

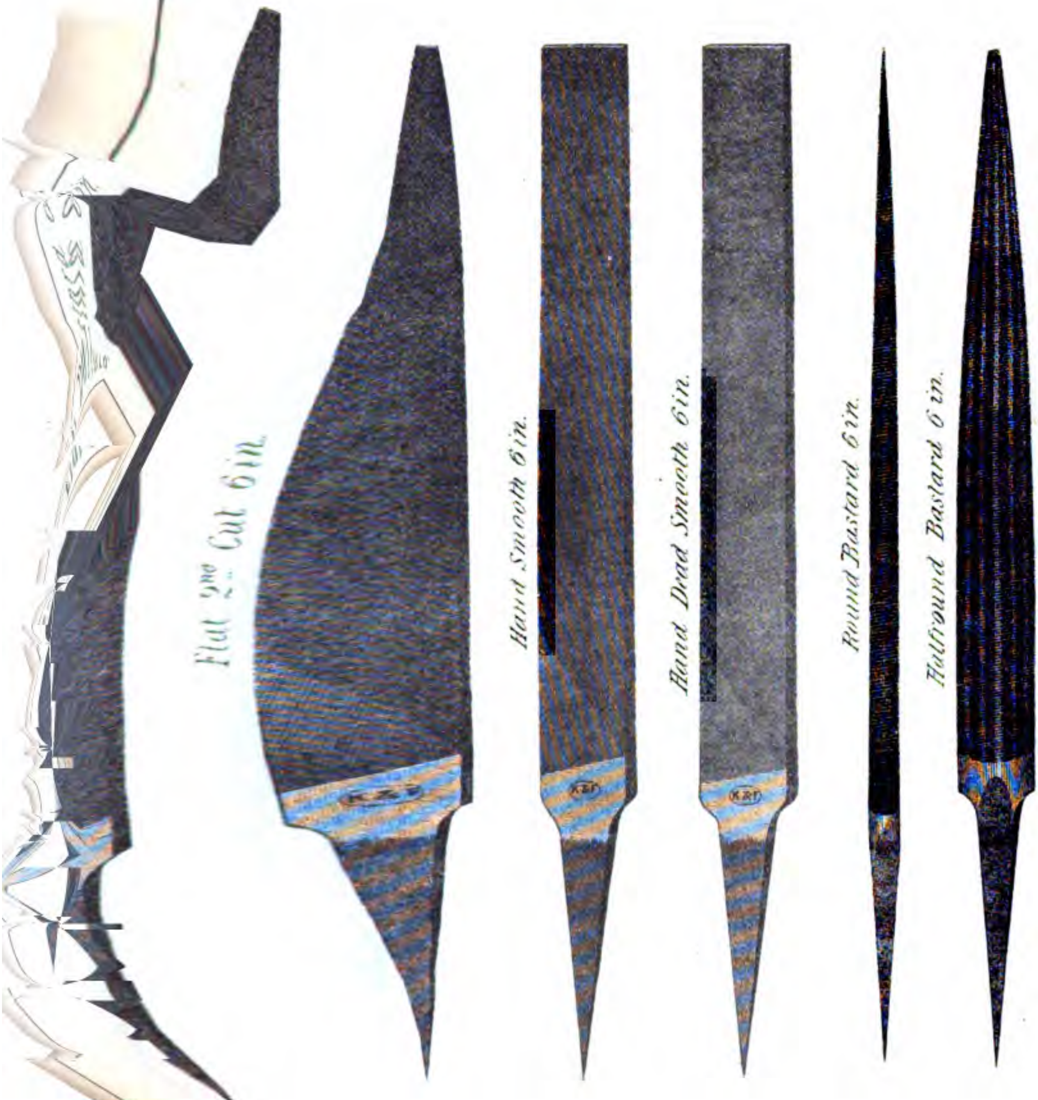
| Kind. | Cut. | Length in inches. |
|---|---|---|
| Cant, blunt | | |
| Cotter, taper | | |
| Cross, or crossing | | |
| Doctor | Double | |
| Entering | | |
| Feather-edge | | |
| Flat boot-heel | Coarse | 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18. |
| Half-round, high back | Double | |
| Mill | Cut double | |
| Nicking, or marking | Double | 4, 5, 6, 7, 8, 9, 10, 11, and 12. |
| Pillar | Bastard | |
| Pillar | Second | 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18. |
| Pillar | Smooth | |
| Round-off | Single | 6, 7, 8, 9, 10, 11, and 12. |
| Slotting | Double | |
| Three-square | Double | |
| Tumbler | Double | |
| Warding (round edge or drill) | Single | |
| Roller | Single | |
| Flat "file rasp" | File and rasp | 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18. |
| Half round "file rasp" | File and rasp | |
| Flat shoe | Rasp | 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14. |
| Oval shoe | Rasp | 6, 7, 8, 9, 10, 11, and 12. |
| Jig | Rasp | |

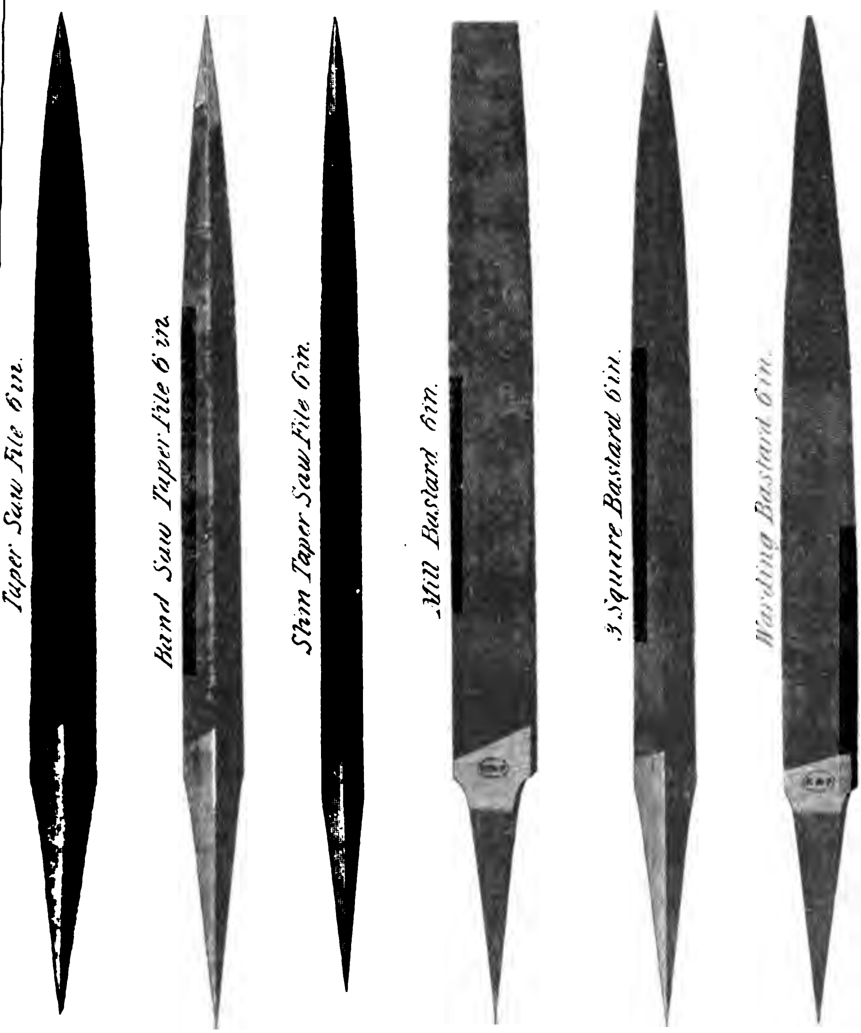
### 6.—NICHOLSON'S EXTRAS AND SPECIALTIES.

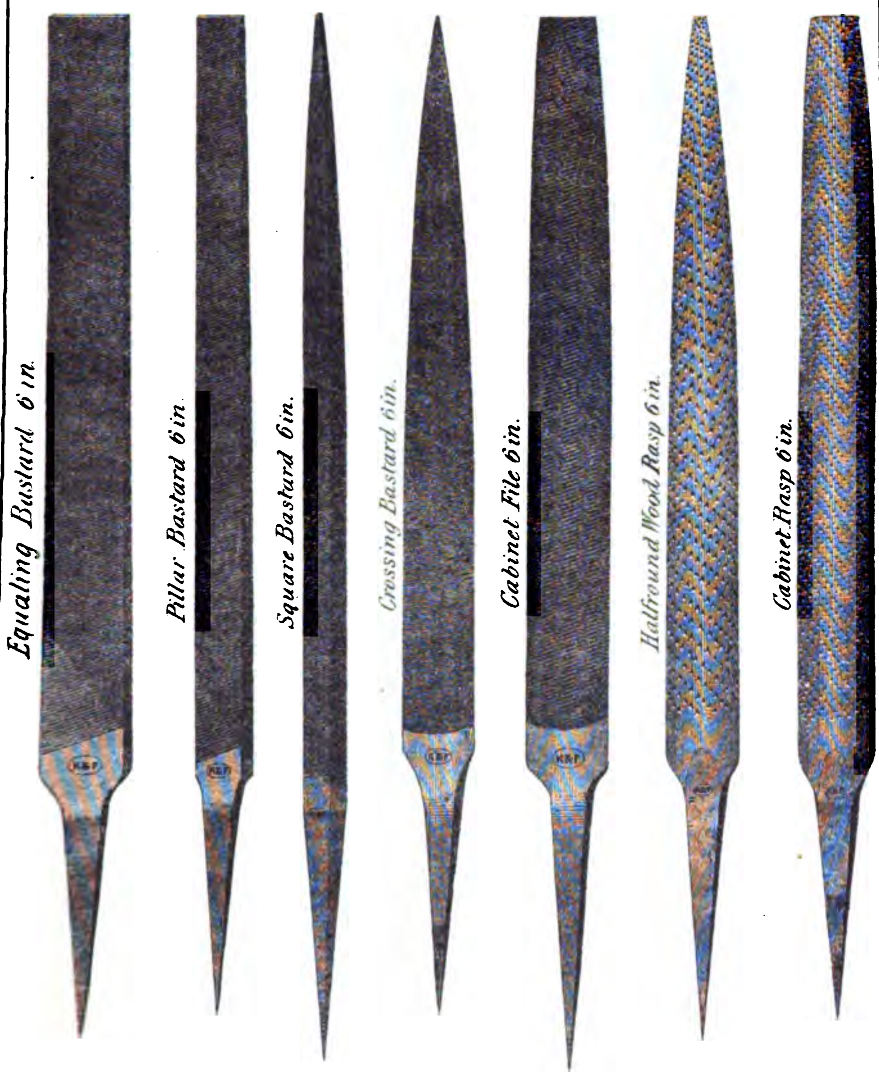
| | | |
|---|---|---|
| Blunts. | Brass coarse cut. | Stub files and holders. |
| Bevel-edge horse rasps. | Lead floats. | Butchers' steels. |
| Files with two round edges. | Dead-smooth. | Machinists' scrapers. |
| Finishing files. | Horse-mouth rasps. | Vise file-holders. |
| Union-cut files. | Bread rasps. | Surface file-holders. |
| Equaling. | Bent rifflers. | File cards and file brushes. |

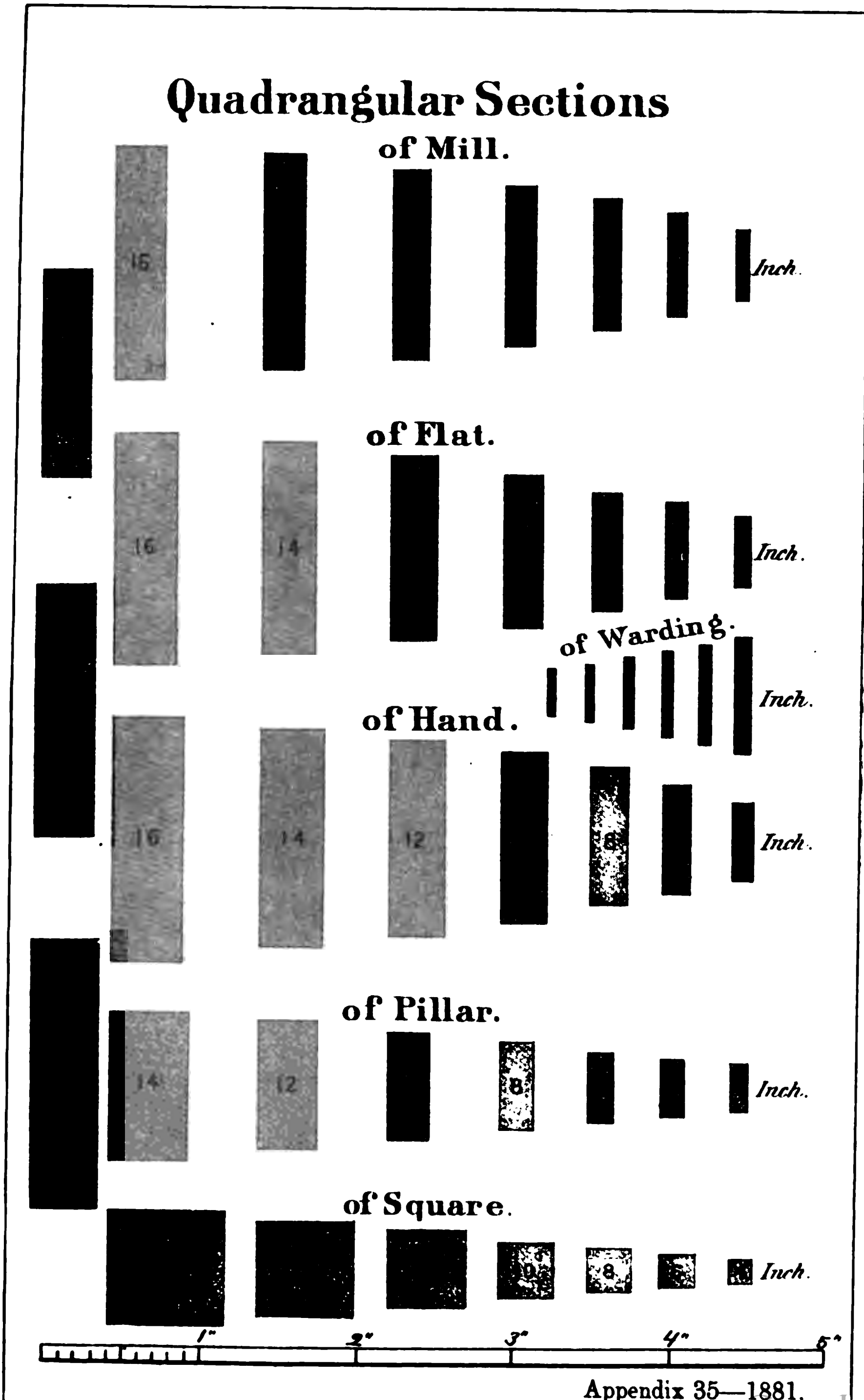

Cuts of Files and Rasps.
Rough.
Bastard.
2nd Cut
Smooth.
Dead Smooth.
Mill Bastd
Mill 2nd Cut.
RASPS
Bastard.
2nd Cut.
Smooth.
Diagrams of Standard. Sizes. Stubs Cuts and Shapes.
Flat & Hand
Round.
Square.
Crossing.
Halfround.
Three Square
Pillar.
1"
2"
3"
4"
5"


Diagrams of Standard Sizes of Regular Files.
Hand
Flat
Halfround
Round
Square
Three Square
Warding
Crossing
Halfround Cab^t Rasps & Files
Halfround Wood Rasps
Mill
Taper
Taper Slim

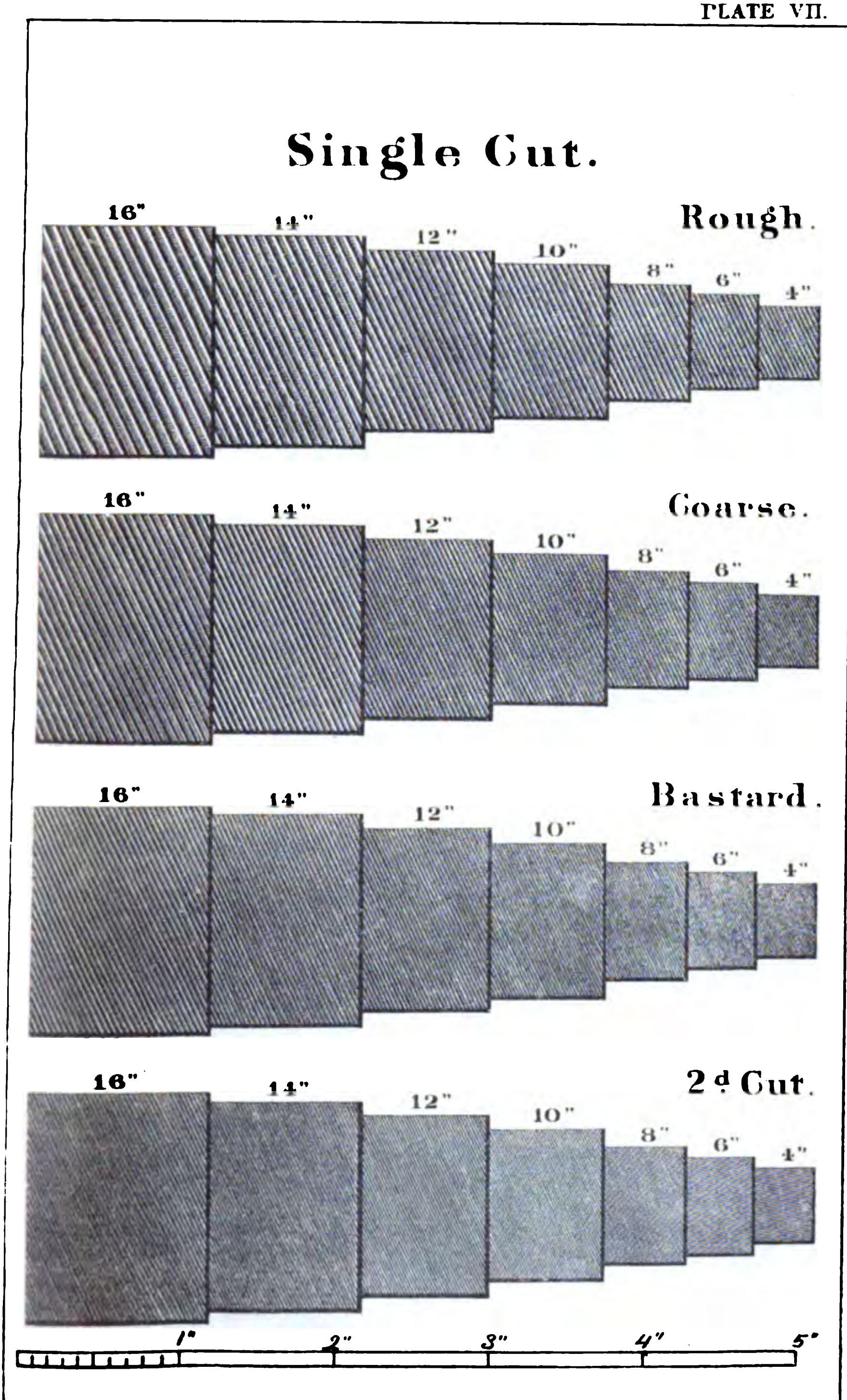

Flat 2nd Cut 6 in.
Hand Smooth 6 in.
Hand Dead Smooth 6 in.
Round Bastard 6 in.
Halfround Bastard 6 in.

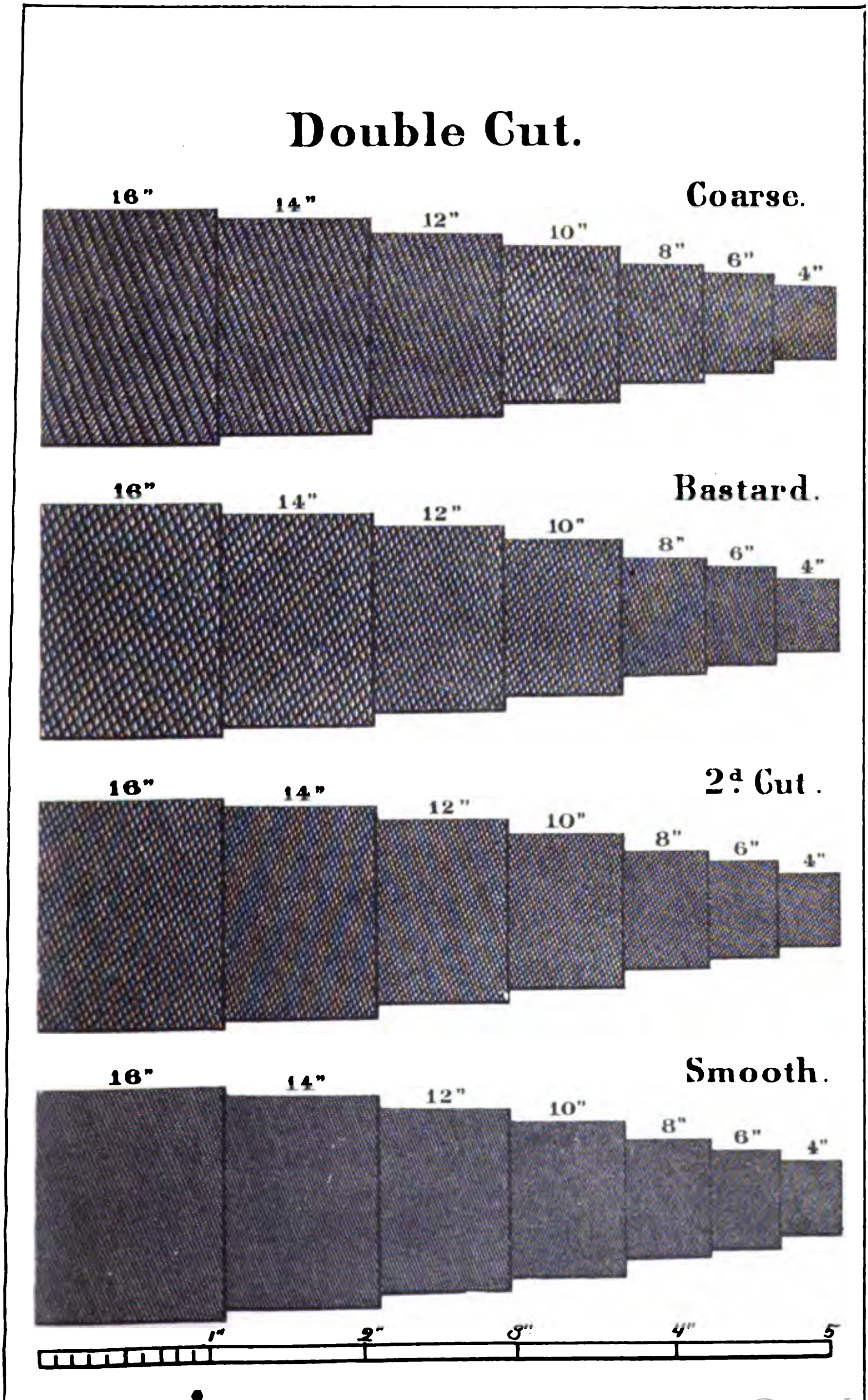

Taper Saw File 6 in.
Band Saw Taper File 6 in.
Shim Taper Saw File 6 in.
Mill Bastard 6 in.
3 Square Bastard 6 in.
Warding Bastard 6 in.

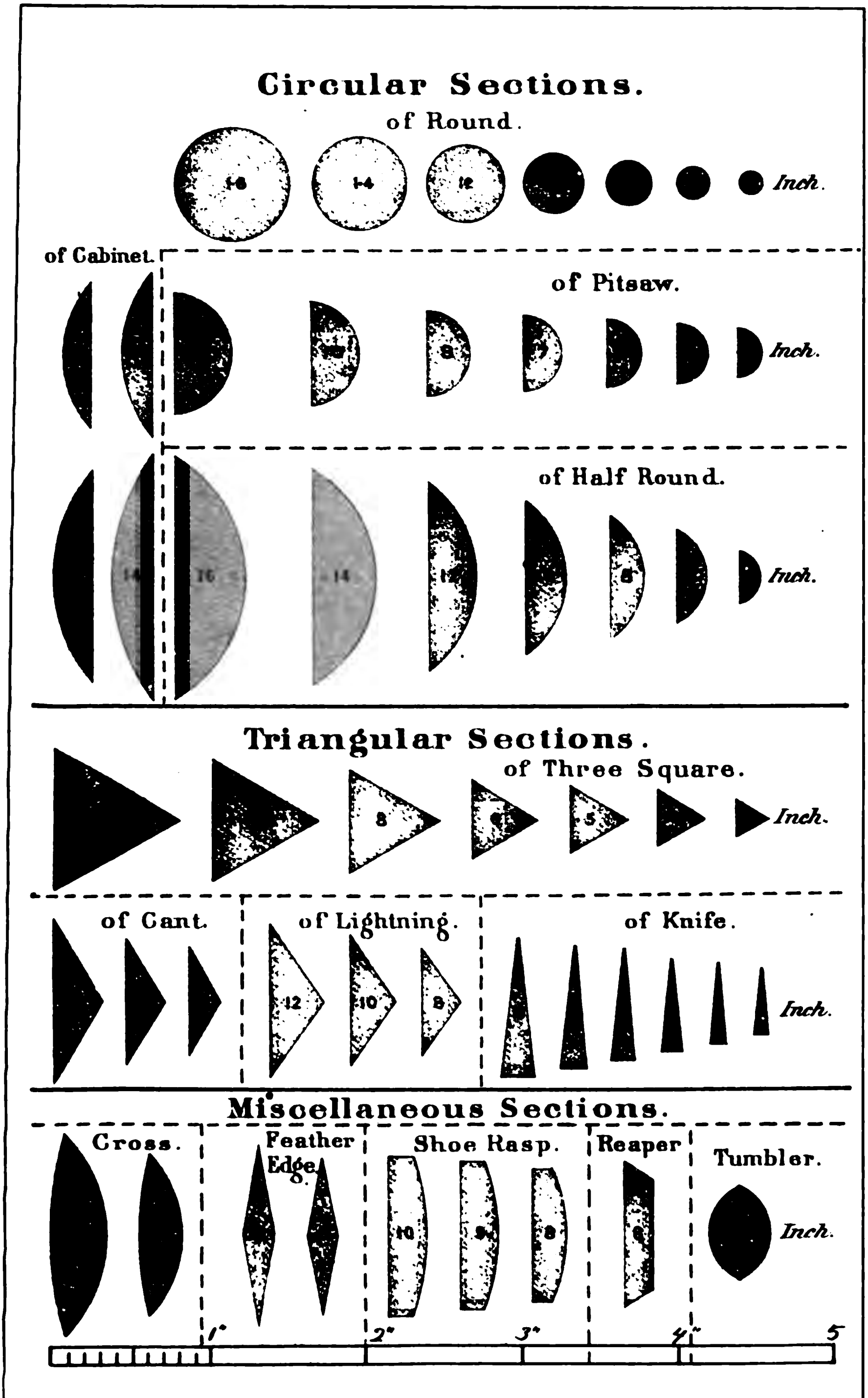

Equaling Bastard 6 in.
Pillar Bastard 6 in.
Square Bastard 6 in.
Crossing Bastard 6 in.
Cabinet File 6 in.
Halfround Wood Rasp 6 in.
Cabinet Rasp 6 in.

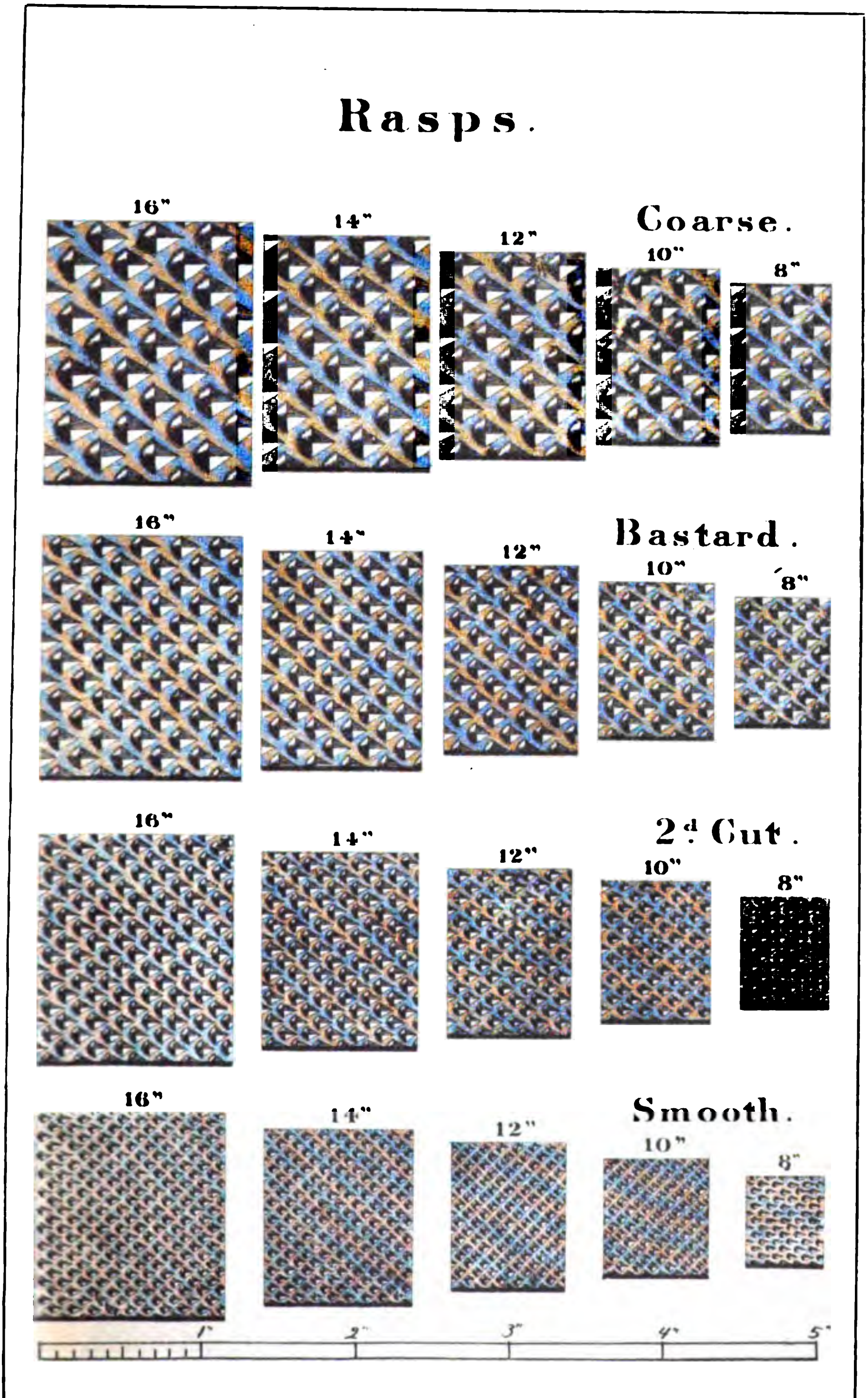



Appendix 35—1881.

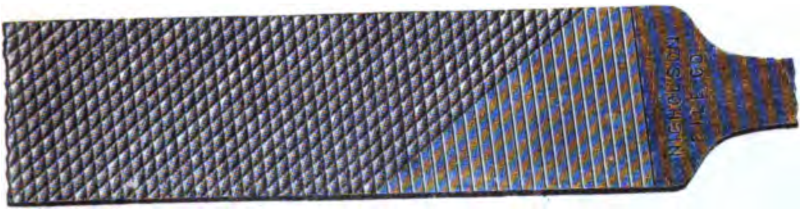

Single Cut.
Rough.
16"
14"
12"
10"
8"
6"
4"
Coarse.
16"
14"
12"
10"
8"
6"
4"
Bastard.
16"
14"
12"
10"
8"
6"
4"
2d Cut.
16"
14"
12"
10"
8"
6"
4"
1"
2"
3"
4"
5"


Double Cut.
Coarse.
16"
14"
12"
10"
8"
6"
4"
Bastard.
16"
14"
12"
10"
8"
6"
4"
2d Cut.
16"
14"
12"
10"
8"
6"
4"
Smooth.
16"
14"
12"
10"
8"
6"
4"
1"
2"
3"
4"
5"

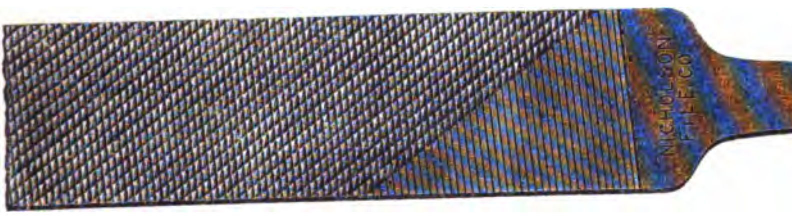

Circular Sections.
of Round.
Inch.
of Cabinet.
of Pitsaw.
Inch.
of Half Round.
Inch.
Triangular Sections.
of Three Square.
Inch.
of Cant.
of Lightning.
of Knife.
Inch.
Miscellaneous Sections.
Cross.
Feather Edge.
Shoe Rasp.
Reaper
Tumbler.
Inch.
1"
2"
3"
4"
5


Rasps.
16"
14"
12"
Coarse.
10"
8"
16"
14"
12"
Bastard.
10"
8"
16"
14"
12"
2d Cut.
10"
8"
16"
14"
12"
Smooth.
10"
8"
1"
2"
3"
4"
5"

BRASS COARSE.

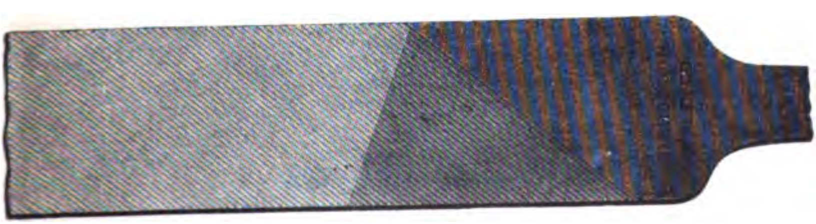



BRASS BASTARD.

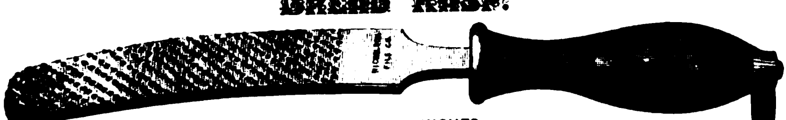



LEAD FLOAT.


FINISHING 2D CUT.



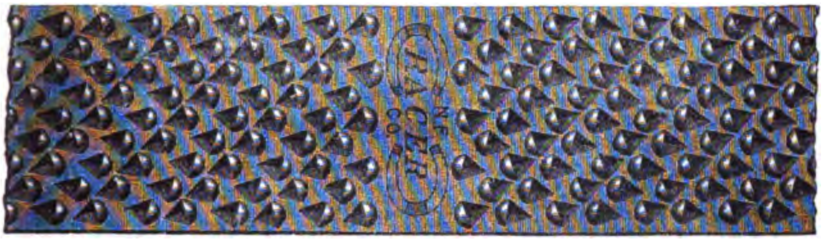
BREAD RASP.



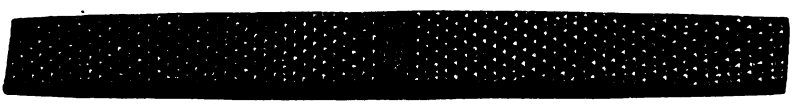
FULL SIZE—12 INCHES.

# IMPROVED HORSE RASPS.

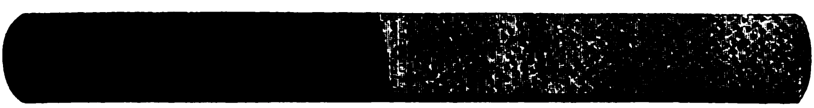
PATENTED.



## RASPS—HORSE.—



## JIG RASP.



## ROLLER FILE.

## Handsaw Tapers

SLIM.

REGULAR.

## Double Ender

## Handsaw File and Handle.

Patented January 1st, 1878.

## Steel Files and Holder.

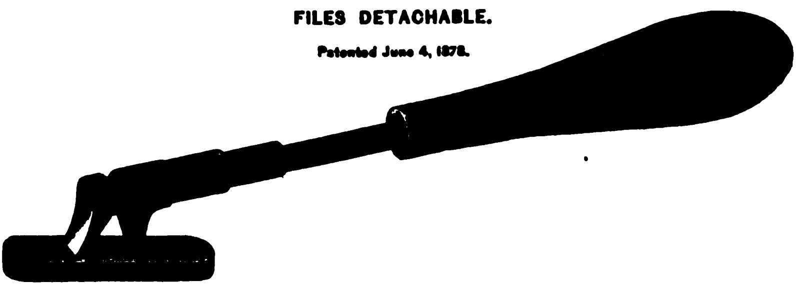
FILES DETACHABLE.

Patented May, 1878.

PILLAR. REAPER. PITSAW. THREE SQUARE. CABINET.

FILES DETACHABLE.

Patented June 4, 1878.



## Improved Butchers' Steels.

Patented December 25th, 1877.

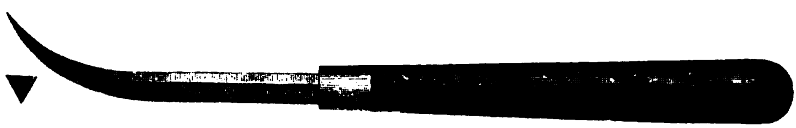
REGULAR STEEL.

PATENT STEEL.

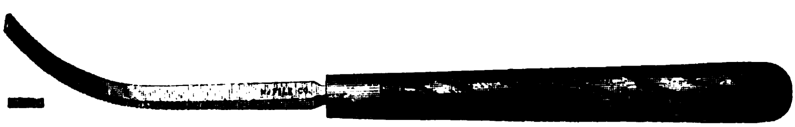
## Bent Rifflers—Handled.

HALF-ROUND BASTARD.

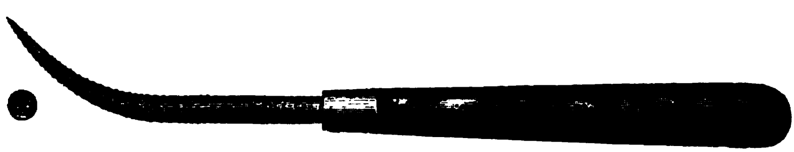
THREE-SQUARE RASP.



THREE-SQUARE BASTARD.



HAND BASTARD.

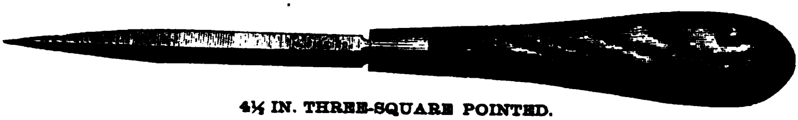


ROUND RASP.

FLAT FLOAT (Safe Sides).

# MACHINISTS' SCRAPERS.

**KIT No. 1.**

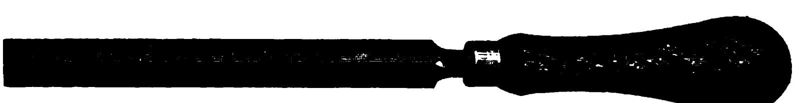


4½ IN. THREE-SQUARE POINTED.

6 IN. CANT BLUNT.

10 IN. ROUND BLUNT.

6 IN. HALF-ROUND BLUNT.

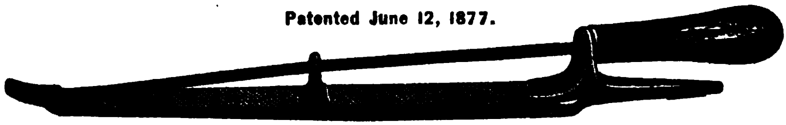


4 IN. THREE-SQUARE BLUNT.

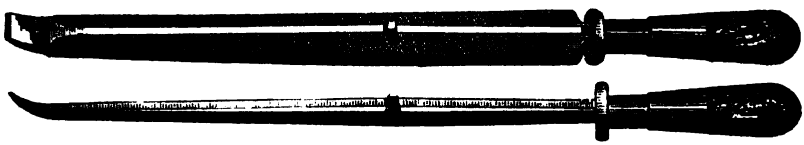
6 IN. MILL BLUNT.

# FILE HOLDERS.

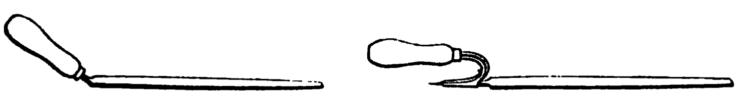
Patented June 12, 1877.



SURFACE FILE HOLDER.

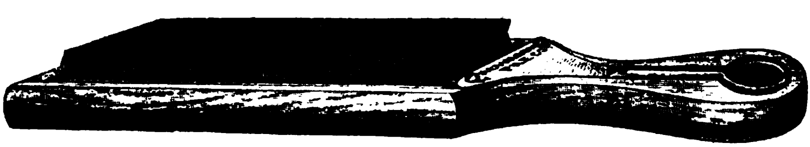


VISE FILE HOLDER.

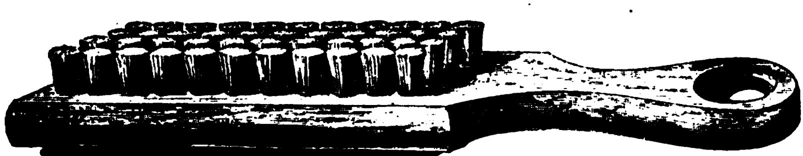


## FILE CLEANERS.

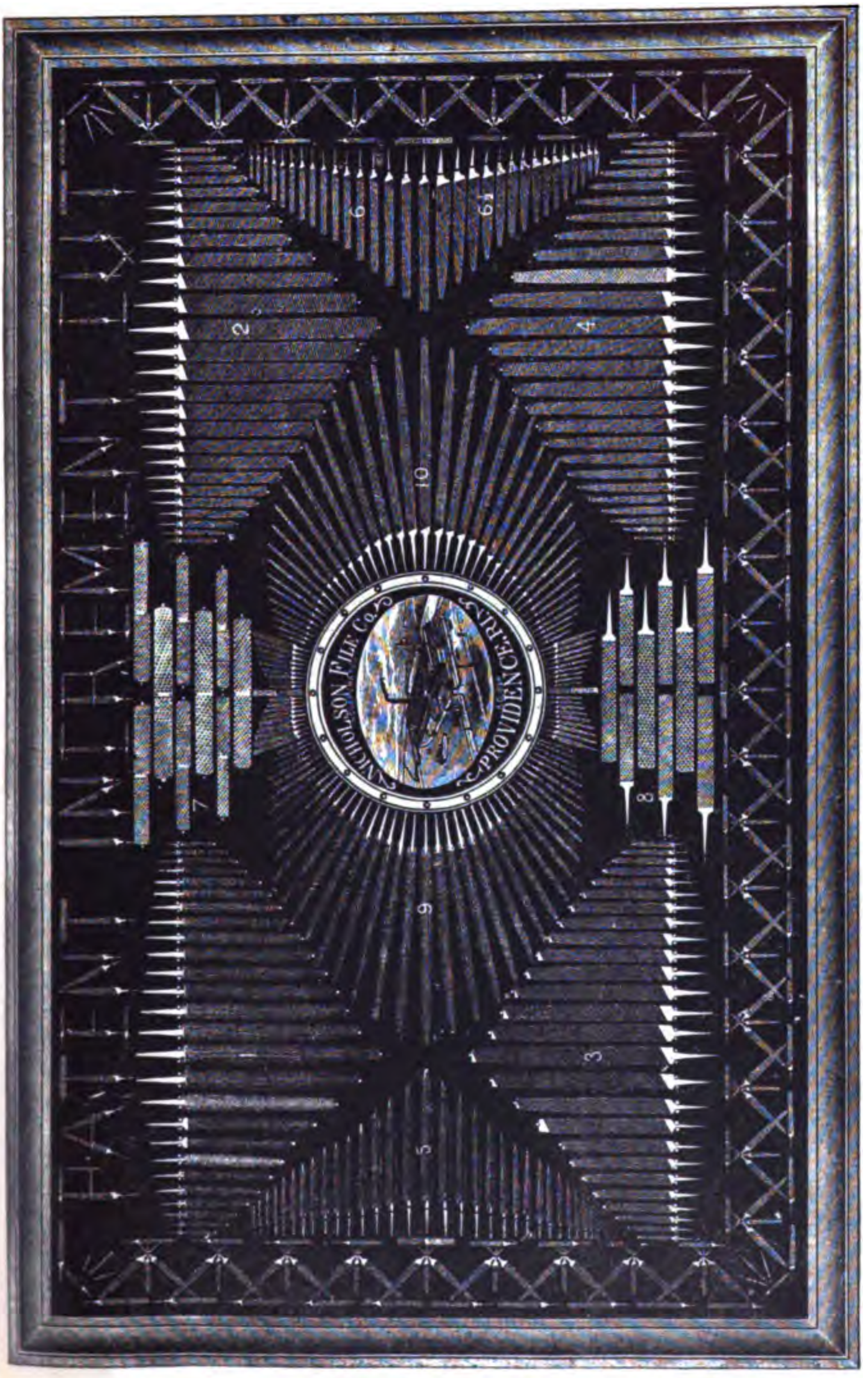
Patented Feb. 12, 1878.



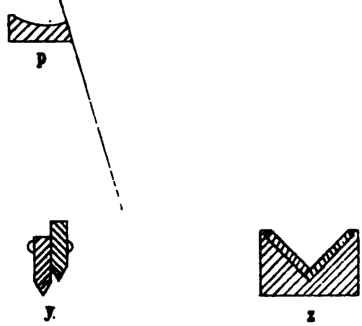
FILE CARD.



FILE BRUSH.




1—HALF-ROUND FILES.
2—HAND.
3—MILL.
4—FLAT
5—THREE-SQUARE.
6—PILLAR.
6½—KNIFE.
7—PLAIN RASPS.
8—TANGED RASPS.
9—ROUND.
10—SQUARE.




# FILES AND RASPS.

DIAGRAMS

SHOWING

TIONS AND SHAPES OF FILES,

TAKEN FROM

Knight's "Mechanical Dictionary."

1881.

Appendix 35–1881

PLATE XX.

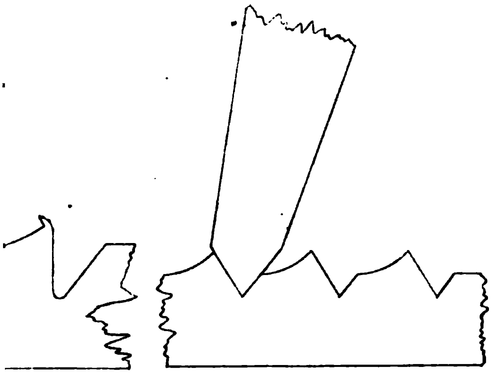


Fig. 2.

FILES AND RASPS.

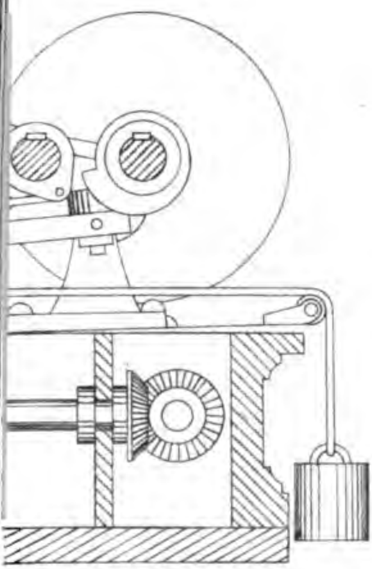
LE-CARRIER, FILING-BLOCK,

AND

ıms showing effects of Inclination of the Chisel,
and the angles to which the cutting
edges are ground

1881.

PLATE XXI.



LES AND RASPS.

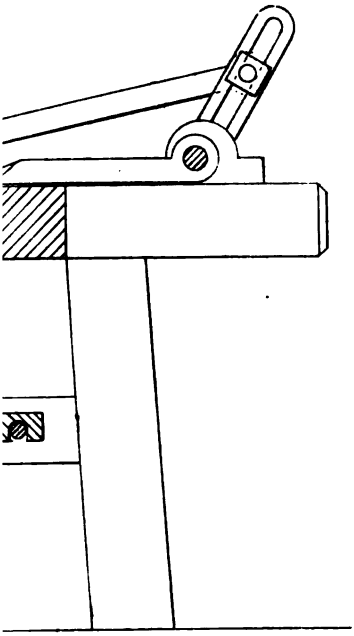
STUDLEY'S FILE-CUTTER,

AND

am & Holden's File-Cutting Machine.

1881.

PLATE XXII.



# ..ES AND RASPS.

## ..OCATING FILING-MACHINE,

AND

## ..E-STRIPPING MACHINE.

1881.

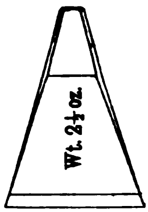



Fig. 7.

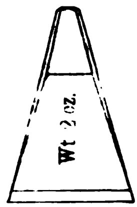



Fig. 8.


Fig. 20.

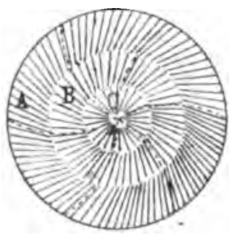



Fig. 28.

# FILES AND RASPS.

# CUTTER'S CHISELS AND PUNCHES,

AND

**ams showing edges of Chisels (enlarged), and ethod of cutting the ends of Rotary Files.**

*Used at the National Armory, Springfield, Mass.*

1881.

PLATE XXIV.

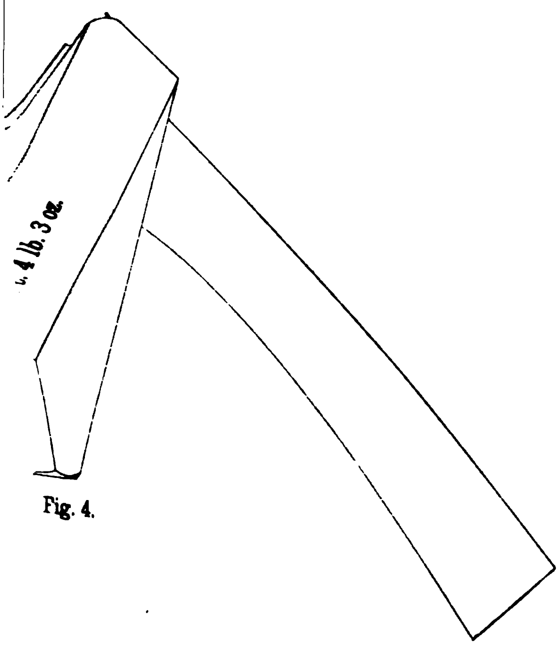



Fig. 4.

# FILES AND RASPS.

## FILE-CUTTER'S HAMMERS,

USED AT THE

## National Armory, Springfield, Mass.

1881.

PLATE XXIV.

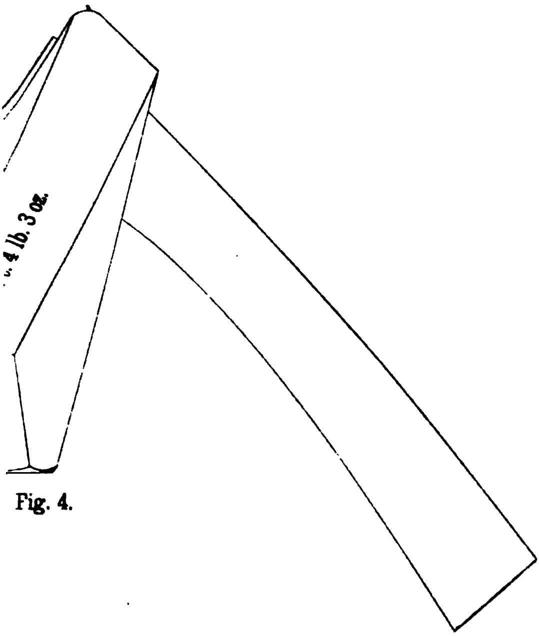



Fig. 4.

# FILES AND RASPS.

## ILE-CUTTER'S HAMMERS,

USED AT THE

## National Armory, Springfield, Mass.

1881.

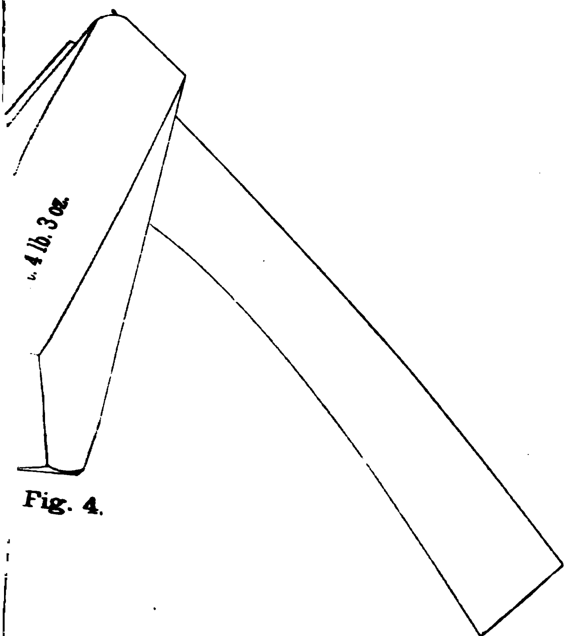



Fig. 4.

FILES AND RASPS.

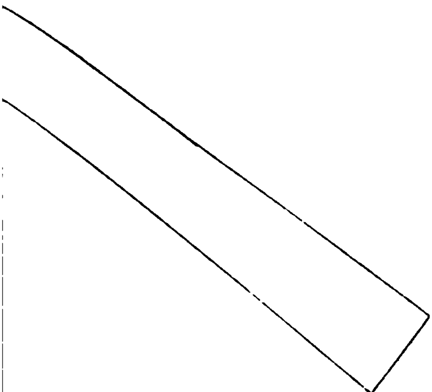
FILE-CUTTER'S HAMMERS,

USED AT THE

National Armory, Springfield, Mass.

1881.

PLATE XXV.



FILES AND RASPS.

FILE-CUTTER'S HAMMERS,

USED AT THE

National Armory, Springfield, Mass.

1881.

PLATE XXVI.

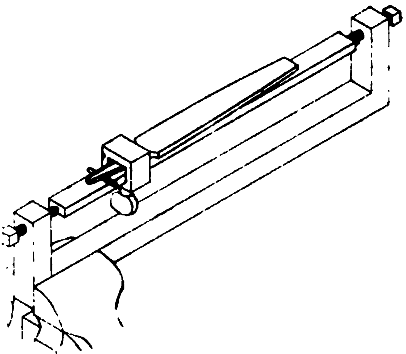


Fig. 2.

FILES AND RASPS.

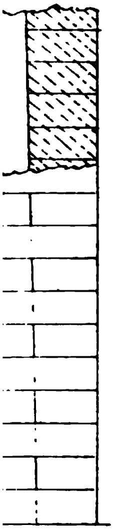
-CUTTER'S ANVIL, STRIPPING FRAME,

File-Racks and Oil Cup.

Used at the National Armory, Springfield, Mass.

1881.

PLATE XXVII.



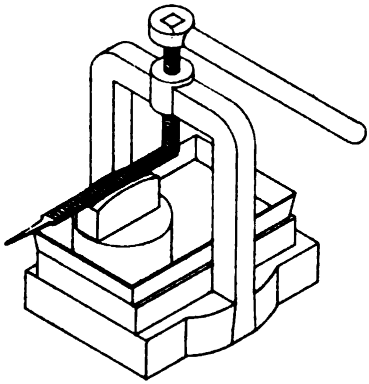


Fig. 5.

# 'ILES AND RASPS.

Diagrams showing Furnace

FOR

## ING FILES FOR HARDENING,

AND

### Methods of Straightening Files.

d at the National Armory, Springfield, Mass.

1881.

PLATE XXVIII.

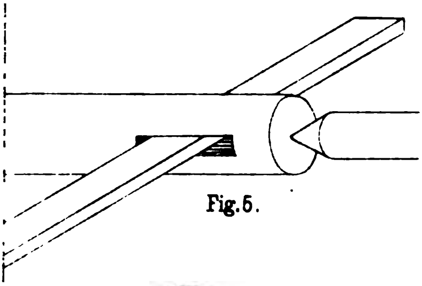


Fig. 5.

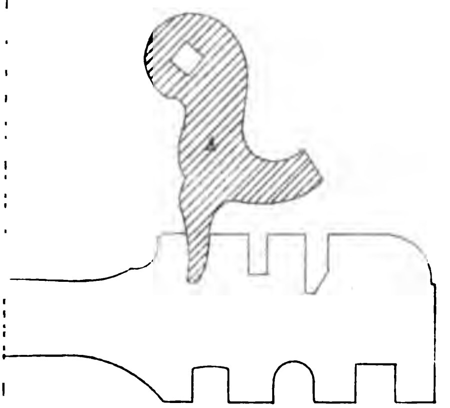


Fig. 9.

FILES AND RASPS.

DIAGRAMS

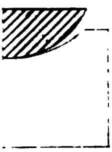
SHOWING

ETHODS OF FILING AND GAUGING

Different Kinds of Work.

1881.

PLATE XXIX.



g.2.

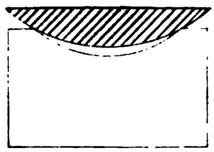


Fig.1.

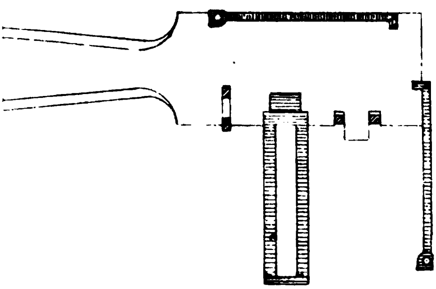


Fig.10.

ILES AND RASPS.

DIAGRAMS

—SHOWING—

ODS OF FILING AND GAUGING

Different Kinds of Work.

1881.

# APPENDIX 36.

## SHOWING STATION AND DUTIES OF THE OFFICERS OF THE ORDNANCE DEPARTMENT ON THE 1st OF OCTOBER, 1881.

| Rank and name. | Duty. | Address. |
|---|---|---|
| BRIGADIER-GENERAL. | | |
| Stephen V. Benét | Chief of Ordnance | Washington, D. C. |
| COLONELS. | | |
| 1. T. T. S. Laidley, brevet | Commanding the Watertown Arsenal | Watertown, Mass. |
| 2. J. McAllister | Commanding the Benicia Arsenal | Benicia, Cal. |
| 3. | | |
| LIEUTENANT-COLONELS. | | |
| 1. S. Crispin, brevet colonel | Commanding the Ordnance Agency; president of the Ordnance Board, and Constructor of Ordnance. | Corner of Houston and Greene streets, N. Y. Post-office box 1811. |
| 2. T. G. Baylor, brevet colonel. | Commanding the New York Arsenal, and member of the Ordnance Board. | Governor's Island, New York Harbor. Post-office box 1449. |
| 3. J. M. Whittemore | On duty in the office of the Chief of Ordnance. | Washington, D. C. |
| 4. A. R. Buffington, brevet | Commanding the Watervliet Arsenal, and member of the Board on Heavy Ordnance and Projectiles. | West Troy, N. Y. |
| MAJORS. | | |
| 1. D. W. Flagler, brevet lieutenant-colonel. | Commanding the Rock Island Arsenal | Rock Island, Ill. |
| 2. A. Mordecai, brevet lieutenant-colonel. | Member of the Ordnance Board | Governor's Island, New York Harbor. Post-office box 1449. |
| 3. S. C. Lyford, brevet lieutenant-colonel. | Commanding the Frankford Arsenal | Philadelphia, Pa. |
| 4. F. H. Parker, brevet | Commanding the Piccatinny Powder Depot, and member of the Board on Heavy Ordnance and Projectiles. | Dover, N. J. |
| 5. J. P. Farley | Commanding the Kennebec Arsenal | Augusta, Me. |
| 6. L. S. Babbitt | Commanding the Fort Monroe Arsenal | Old Point Comfort, Va. |
| 7. W. A. Marye | Commanding the Augusta Arsenal | Augusta, Ga. |
| 8. I. Arnold, jr | Commanding the Indianapolis Arsenal | Indianapolis, Ind. |
| 9. C. Comly | Instructor of ordnance and gunnery, United States Military Academy. | West Point, N. Y. |
| 10. J. R. McGinness | Commanding the Saint Louis Powder Depot. | Jefferson Barracks, Mo. |
| CAPTAINS. | | |
| 1. J. H. Rollins, brevet | On sick leave of absence | Columbia, Mo. |
| 2. G. W. McKee, brevet major | Assistant, Rock Island Arsenal | Rock Island, Ill. |
| 3. F. H. Phipps, brevet | Commanding the San Antonio Arsenal, and chief ordnance officer, Department of Texas. | San Antonio, Tex. |
| 4. J. W. Reilly, brevet | Commanding the Allegheny Arsenal | Pittsburgh, Pa. |
| 5. J. A. Kress, brevet major | Commanding the Vancouver Arsenal, and chief ordnance officer, Department of the Columbia. | Vancouver, Wash. |
| 6. O. E. Michaelis, brevet | Assistant, Frankford Arsenal | Philadelphia, Pa. |
| 7. C. E. Dutton | On duty under the Interior Department | Geological Survey, Washington, D. C. |
| 8. J. G. Butler | Assistant, Watertown Arsenal | Watertown, Mass. |
| 9. C. Bryant | Assistant to the Constructor of Ordnance. | South Boston Foundry, Boston, Mass. |
| 10. A. L. Varney | Assistant, Watervliet Arsenal | West Troy, N. Y. |
| 11. J. C. Clifford | do | Do. |
| 12. J. E. Greer | Assistant, National Armory | Springfield, Mass. |
| 13. J. Pitman | Assistant, Watertown Arsenal (on duty under the Interior Department). | Newport, R. I. |
| 14. C. Shaler | Assistant to Constructor of Ordnance | South Boston Foundry, Boston, Mass. |

SHOWING STATION AND DUTIES OF THE OFFICERS OF THE ORDNANCE DEPARTMENT, &c.—Continued.

| Rank and name. | Duty. | Address. |
|---|---|---|
| 15. H. Metcalfe | Assistant, Frankford Arsenal, and inspector of contract ammunition. | Philadelphia, Pa. |
| 16. W. S. Starring | Assistant to the Constructor of Ordnance. | Corner of Houston and Greene streets, N. Y. Post-office box 1811. |
| 17. C. S. Smith | Assistant, Ordnance Agency | Do. |
| 18. S. E. Blunt | Chief ordnance officer, Department of Dakota. | Saint Paul, Minn. |
| 19. F. Heath | Commanding the Cheyenne Ordnance Depot. | Cheyenne, Wyo. |
| 20. D. M. Taylor | Chief ordnance officer, Department of the Missouri, and commanding the Fort Leavenworth Ordnance Depot. | Fort Leavenworth, Kans. |
| FIRST LIEUTENANTS. | | |
| 1. D. A. Lyle | Assistant, National Armory, and member of the Board on Life-Saving Apparatus, &c., under the Secretary of the Treasury. | Springfield, Mass. |
| 2. J. Rockwell, jr | Commanding the Fort Abraham Lincoln Ordnance Depot. | Fort Abraham Lincoln, Dak. |
| 3. J. C. Ayres | Assistant, National Armory | Springfield, Mass. |
| 4. M. W. Lyon | Assistant, Frankford Arsenal | Philadelphia, Pa. |
| 5. C. W. Whipple | Assistant to the Constructor of Ordnance, | West Point Foundry, Cold Spring, N. Y. |
| 6. A. H. Russell | Assistant, Watertown Arsenal | Watertown, Mass. |
| 7. R. Birnie, jr | Assistant to Constructor of Ordnance | West Point Foundry, Cold Spring, N. Y. |
| 8. I. MacNutt | Chief ordnance officer, Department of the South. | Newport, Ky. |
| 9. C. C. Morrison | Assistant, National Armory | Springfield, Mass. |
| 10. F. Baker | Assistant, Benicia Arsenal | Benicia, Cal. |
| 11. O. B. Mitcham | Assistant, Rock Island Arsenal | Rock Island, Ill. |
| 12. H. D. Borup | Assistant, Frankford Arsenal | Philadelphia, Pa. |
| 13. L. L. Bruff | Assistant, Rock Island Arsenal | Rock Island, Ill. |
| 14. C. H. Clark | Acting assistant instructor of ordnance and gunnery. | West Point, N. Y. |
| 15. W. M. Medcalfe | Acting assistant professor of mathematics. | Do. |
| 16. William Crozier | ......do | Do. |
| ORDNANCE STOREKEEPERS. | | |
| E. Ingersoll, major | On duty, National Armory | Springfield, Mass. |
| W. R. Shoemaker, captain | Commanding the Fort Union Arsenal | Fort Union, N. Mex. |
| B. H. Gilbreth, captain | On sick leave of absence | West Newton, Mass. |
| E. D. Ellsworth, captain | ......do | Mechanicsville, N. Y. |
| W. Adams, captain | On duty, Fort Monroe Arsenal | Old Point Comfort, Va. |
| A. S. M. Morgan, captain | On duty, Allegheny Arsenal | Pittsburgh, Pa. |
| W. H. Rexford, captain | On duty, Indianapolis Arsenal | Indianapolis, Ind. |
| F. Whyte, captain | On sick leave of absence | Washington, D. C. |
| D. J. Young, captain | On duty, Watervliet Arsenal | West Troy, N. Y. |
| M. J. Grealish, captain | On duty, Augusta Arsenal | Augusta, Ga. |

## REPORTS OF THE CONSTRUCTOR OF ORDNANCE.

OFFICE OF THE CONSTRUCTOR OF ORDNANCE,
*New York City, October* 8, 1881.

SIR: I have the honor to transmit herewith the following official papers to accompany your annual report, viz:

Construction report of 11-inch breech-loading chambered rifle, with one plate.

Construction report of 11-inch muzzle-loading chambered rifle, with one plate.

Construction report of 8-inch breech-loading chambered rifle, with one plate.

Construction report on 3.20-inch breech-loading chambered rifles, with one plate.

Construction report on carriage for 3.20-inch breech-loading chambered rifle, and with description of the Engelhardt field carriage (a translation).

Progress report on construction of four 12-inch breech-loading chambered rifles and carriage, with one plate.

Progress report on construction of 12-inch breech-loading chambered rifled howitzer and carriage, one plate.

Progress report on plant for fabrication of 12-inch breech-loading rifles.

Report on tests of Firth's steel.

Progress report on experimental cannon powders.

The above construction reports on guns and carriages were prepared by the assistants to the Constructor of Ordnance, who have had charge of their fabrication. The signature of the writer is attached to the reports on tests of steel, and experimental cannon powders.

Very respectfully, your obedient servant,

CHAS. S. SMITH,

*Captain of Ordnance, U. S. A., Assistant to Constructor of Ordnance.*

The CHIEF OF ORDNANCE, U. S. A.,

*Washington, D. C.*

# APPENDIX 37.

## CONSTRUCTION REPORT OF AN 11-INCH BREECH-LOADING CHAMBERED RIFLE, CONVERTED FROM A 15-INCH RODMAN SMOOTH-BORE, BY LINING WITH A STEEL JACKETED COILED WROUGHT-IRON TUBE INSERTED FROM THE BREECH, JACKET OF THE TUBE BEING PROLONGED TO THE REAR, AND ADAPTED FOR THE INSERTION OF THE ROUND WEDGE FERMETURE.

(One plate.)

This piece consists of a cast-iron casing, which contains a compound lining of steel and wrought iron and is reinforced by a steel breech-band. The breech is closed by a steel block which has a lateral motion, after the Krupp system. The casing was obtained by cutting off a 15-inch Rodman smooth-bore gun to a length of 173″.5, turning down the breech to receive the band and boring up the interior to prepare it for the lining. The compound lining is a coiled wrought-iron tube of the same length as the casing, reinforced by a steel breech-receiver, shrunk on to cover it for a distance of 75″ from the base. The breech-receiver projects 32″.75 to the rear of the tube and casing, and is mortised for the reception of the breech-block, and parts of its mechanism. The steel breech-band embraces the rear of the casing with a shrinkage of 0″.03, and is secured by three pins equidistant from each other, parallel to the axis of the bore, and halved into the exterior of the casing and interior of the band.

The breech mechanism is identical in its operation with that of the 8″ breech-loading rifle, described in Report of the Chief of Ordnance 1878, pp. 359 and 360.

### RIFLING, CHAMBERING, AND VENTING.

The gun contains 50 grooves and lands.

| | |
|---|---|
| Depth of grooves | 0″.08 |
| Width of grooves | 0″.46 |
| Width of lands | 0″.2303 |

Twist uniform. One turn in 45 calibers = 41′.25. The powder-chamber is 39″.12 long. It is cylindrical in shape, 12″ in diameter for a distance of 35″.12 from the breech, and terminates in a conic frustum 4″ long with a least diameter of 11″.22. In front of the chamber is a seat for the base of the projectile 1″.9 long and 11″.22 in diameter. A conic frustum 1″.4 long connects the seat with the surface of the lands. The axis of the vent 10″ from the breech of casing is perpendicular to the axis of the bore, and 2″.5 to the left of this axis.

### FABRICATION.

The conversion was carried on at the South Boston foundry. The casing was made from the 15″ Rodman smooth-bore No. 130, fabricated at the same foundry in ———. The density and tenacity of the metal were as follows:

| | |
|---|---|
| Density | 7.2502 |
| Tenacity, pounds | 32.346 |

The wrought-iron tube was manufactured at the West Point foundry from Ulster tube iron in six coiled sections. The bars for the two rear sections were 2″.75 square, those for the middle section were 4″ by 3″.35, and hexagonal in form; those for the three forward sections were 2″.75 square. The sections were butt-welded together, bored up to 11″, turned down to a diameter a little in excess of that required for the finished tube, and subjected to a water pressure of 180 pounds.

A mean of five results gave the physical characteristics of specimens taken from the bars as follows:

| | |
|---|---|
| Tenacity, pounds | 48,500 |
| Elastic limit, pounds | 25,667 |
| Elongation per inch, at rupture | 0″.289 |
| Length of specimen between shoulders | 3″.000 |
| Original area of cross section | 0″.25 |

A solid forging was welded to the rear of the tube, and bored out to form a seat for the gas-check. The breech-receiver, block, and band were made of English steel received from Firth & Co., of Sheffield. The receiver and band were oil-tempered. The physical characteristics of steel specimens taken from the receiver are shown in an appended table.

To prepare the casing for the lining it was bored up to 15″.25, recessed for the muzzle-collar, and cut off at the breech to the required length. It was then counterbored as follows:

For 3″ from breech to 34″.
For 6″ additional to 32″.
For 24″.5 additional to 27″.
For 41″.5 additional to 22″.45.
For 2″.5 additional to 16″.75.

The end of each counterbore was rounded off to form a suitable shoulder, and a thread for the breech-receiver 0″.4 deep was cut in the 22″.45 diameter. The exterior of the casing was then turned down to 46″.5 for a distance of 16″ from the breech, and to 46″.448 for an additional distance of 3″ to receive the breech-band. The interior of the breech-receiver was bored up to the diameter required to fit the tube, and the slot was drilled out, planed, and bored for the breech-block.

The wrought-iron tube was chambered, rifled, and recessed for the gas-check. It was then turned to 0″.003 greater diameter than the interior of the breech-receiver. The receiver and tube were shrunk together, and turned down on the exterior to dimensions hereinafter given.

In order to provide for longitudinal expansion of the casing when heated for insertion of the tube, the shoulders upon the jacket were so finished as to prevent contact of the jacket and breech-receiver, until the shoulder of the wrought-iron tube was brought to a firm bearing. The screw-thread was also given sufficient clearance to allow it to be screwed home properly.

The breech-band was turned and bored.

The assemblage of the casing, lining, and breech-band was successfully effected in the same manner as described for the 8″ breech-loading rifle in report of Chief of Ordnance for 1878, pp. 361 and 362.

The breech-block and its appurtenances were meantime completed, and fitted to the slot.

INSPECTION.

The workmanship and finish of the gun were good in every respect.

### PRINCIPAL DIMENSIONS.

| | Inches. |
|---|---|
| Total length of gun | 206.12 |
| Length of cast-iron casing | 173.56 |
| Length of wrought-iron tube | 173.56 |
| Length of steel jacket | 107.75 |
| Length of breech-band | 19 |
| Exterior diameter of breech-band | 52.5 |
| Interior diameter of breech-band | 46.493 |
| Exterior diameter of casing under breech-band | 46.534 |
| Length of neck of tube | 7.20 |
| Length of muzzle-collar | 7.20 |
| Diameter of neck of tube | 13.494 |
| Interior diameter of muzzle-collar | 13.505 |
| Length of recess for muzzle-collar | 7.41 |
| Diameter of recess for muzzle-collar | 15.991 |
| Length of rifled portion of bore | 131.29 |
| Length of cylindrical part of chamber | 35.12 |
| Length of conical part of chamber | 4 |
| Length of chamber, total | 39.12 |
| Length of seat for base of shot | 1.9 |
| Diameter of bore across lands | 11 |
| Diameter of cylindrical part of chamber | 12 |
| Least diameter of conical part of chamber | 11.22 |
| Diameter of seat for base of shot | 11.22 |
| Width of lands | 0.2303 |
| Width of grooves | 0.46 |
| Depth of rifling | 0.08 |
| Twist of rifling, one turn in 45 calibers | 41.25 |
| Length of breech-block | 35.5 |
| Width of breech-block | 14 |
| Thickness through center | 19.7 |
| Width of slot for breech-block | 14.05 |
| Length of translating screw | 37.82 |
| Diameter across threads | 1.745 |
| Length of locking-nut | 7.27 |
| Diameter of locking-nut | 7.525 |
| | Lbs. |
| Weight of gun | 56,6[illegible]9 |
| Preponderance | 874 |

TABLE 1.—*Relative diameters of the interior of steel jacket, and that part of wrought-iron tube over which it was shrunk —11″ breech-loading converted rifle.*

| Inches from front end of jacket. | Interior diameter of jacket. | Exterior diameter of tube. | Difference. | Inches from front end of jacket. | Interior diameter of jacket. | Exterior diameter of tube. | Difference. |
|---|---|---|---|---|---|---|---|
| 1 | 16.739 | 16.739 | .000 | 22 | 16.740 | 16.739 | .001 |
| 2 | 16.739 | 16.739 | .000 | 23 | 16.739 | 16.739 | .000 |
| 3 | 16.738 | 16.739 | + .001 | 24 | 16.739 | 16.739 | .000 |
| 4 | 16.739 | 16.739 | .000 | 25 | 16.740 | 16.741 | .001 |
| 5 | 16.739 | 16.739 | .000 | 26 | 16.740 | 16.741 | .001 |
| 6 | 16.739 | 16.739 | .000 | 27 | 16.740 | 16.741 | .001 |
| 7 | 16.739 | 16.739 | .000 | 28 | 16.740 | 16.741 | .001 |
| 8 | 16.739 | 16.739 | .000 | 29 | 16.740 | 16.741 | .001 |
| 9 | 16.739 | 16.739 | .000 | 30 | 16.740 | 16.741 | .001 |
| 10 | 16.739 | 16.739 | .000 | 31 | 16.740 | 16.741 | .001 |
| 11 | 16.739 | 16.739 | .000 | 32 | 16.740 | 16.741 | .001 |
| 12 | 16.739 | 16.739 | .000 | 33 | 16.740 | 16.741 | .001 |
| 13 | 16.740 | 16.739 | − .001 | 34 | 16.739 | 16.741 | .002 |
| 14 | 16.740 | 16.739 | − .001 | 35 | 16.739 | 16.741 | .002 |
| 15 | 16.740 | 16.739 | − .001 | 36 | 16.740 | 16.741 | .001 |
| 16 | 16.740 | 16.739 | − .001 | 37 | 16.739 | 16.741 | .002 |
| 17 | 16.740 | 16.739 | − .001 | 38 | 16.739 | 16.741 | .002 |
| 18 | 16.740 | 16.739 | − .001 | 39 | 16.739 | 16.741 | .002 |
| 19 | 16.740 | 16.739 | .001 | 40 | 16.739 | 16.741 | .002 |
| 20 | 16.740 | 16.739 | − .001 | 41 | 16.738 | 16.741 | [illegible] |
| 21 | 16.740 | 16.739 | − .001 | 42 | 16.738 | 16.741 | .003 |

TABLE 1.—*Relative diameters of the interior of steel jacket, &c.*—Continued.

| Inches from front end of jacket. | Interior diameter of jacket. | Exterior diameter of tube. | Difference. | Inches from front end of jacket. | Interior diameter of jacket. | Exterior diameter of tube. | Difference. |
|---|---|---|---|---|---|---|---|
| 43 | 16.739 | 16.741 | .002 | 60 | 16.740 | 16.741 | .001 |
| 44 | 16.739 | 16.741 | .002 | 61 | 16.740 | 16.741 | .001 |
| 45 | 16.739 | 16.741 | .002 | 62 | 16.740 | 16.741 | .001 |
| 46 | 16.740 | 16.741 | .001 | 63 | 16.739 | 16.741 | .002 |
| 47 | 16.740 | 16.741 | .001 | 64 | 16.740 | 16.741 | .001 |
| 48 | 16.739 | 16.741 | .002 | 65 | 16.739 | 16.741 | .002 |
| 49 | 16.739 | 16.741 | .002 | 66 | 16.739 | 16.741 | .002 |
| 50 | 16.739 | 16.741 | .002 | 67 | 16.739 | 16.741 | .002 |
| 51 | 16.739 | 16.741 | .002 | 68 | 16.738 | 16.741 | .003 |
| 52 | 16.739 | 16.741 | .002 | 69 | 16.738 | 16.741 | .003 |
| 53 | 16.739 | 16.741 | .002 | 70 | 16.738 | 16.741 | .003 |
| 54 | 16.739 | 16.741 | .002 | 71 | 16.737 | 16.741 | .004 |
| 55 | 16.739 | 16.741 | .002 | 72 | 16.738 | 16.741 | .003 |
| 56 | 16.739 | 16.741 | .002 | 73 | 16.738 | 16.741 | .003 |
| 57 | 16.739 | 16.741 | .002 | 74 | 16.738 | 16.730 | —.008 |
| 58 | 16.739 | 16.741 | .002 | 75 | 16.734 | 16.730 | —.004 |
| 59 | 16.739 | 16.741 | .002 | | | | |

TABLE 2.—*Relative diameters of interior of cast-iron casing, and exterior of tube and jacket united for insertion therein. 11″ breech-loading converted rifle.*

| Distance from muzzle. | Diameter of bore of casing. | Exterior diameter of tube. | Difference. | Distance from muzzle. | Diameter of bore of casing. | Exterior diameter of tube. | Difference. |
|---|---|---|---|---|---|---|---|
| *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 8 | 15.240 | 15.226 | —.014 | 80 | 15.240 | 15.227 | —.013 |
| 10 | 15.241 | 15.226 | —.015 | 82 | 15.240 | 15.227 | —.013 |
| 12 | 15.241 | 15.226 | —.015 | 84 | 15.239 | 15.228 | —.011 |
| 14 | 15.241 | 15.226 | —.015 | 86 | 15.239 | 15.228 | —.011 |
| 16 | 15.240 | 15.226 | —.014 | 88 | 15.239 | 15.228 | —.011 |
| 18 | 15.240 | 15.226 | —.014 | 90 | 15.239 | 15.227 | —.012 |
| 20 | 15.241 | 15.226 | —.015 | 92 | 15.239 | 15.227 | —.012 |
| 22 | 15.241 | 15.226 | —.015 | 94 | 15.239 | 15.227 | —.012 |
| 24 | 15.240 | 15.226 | —.014 | 95 | 15.239 | 15.227 | —.012 |
| 26 | 15.240 | 15.226 | —.014 | 96 | 16.770 | 16.761 | —.009 |
| 28 | 15.241 | 15.226 | —.015 | 97 | 16.767 | 16.761 | —.006 |
| 30 | 15.241 | 15.227 | —.014 | 98 | 16.770 | 16.761 | —.009 |
| 32 | 15.241 | 15.227 | —.014 | 103 | 22.443 | 22.455 | +.012 |
| 34 | 15.241 | 15.227 | —.014 | 104 | 22.444 | 22.455 | .011 |
| 36 | 15.241 | 15.227 | —.014 | 108 | 22.444 | 22.453 | .009 |
| 38 | 15.240 | 15.227 | —.013 | 114 | 22.443 | 22.454 | .011 |
| 40 | 15.240 | 15.227 | —.013 | 120 | 22.443 | 22.455 | .012 |
| 42 | 15.241 | 15.227 | —.014 | 126 | 22.443 | 22.452 | .009 |
| 44 | 15.241 | 15.227 | —.014 | 136 | 23.236 | 23.237 | .001 |
| 46 | 15.241 | 15.227 | —.014 | 138 | 23.239 | 23.239 | .000 |
| 48 | 15.240 | 15.227 | —.013 | 141 | 27.003 | 27.009 | .006 |
| 50 | 15.241 | 15.227 | —.014 | 143 | 27.004 | 27.010 | .006 |
| 52 | 15.241 | 15.128 | —.013 | 145 | 27.004 | 27.009 | .005 |
| 54 | 15.240 | 15.228 | —.012 | 147 | 27.003 | 27.009 | .006 |
| 56 | 15.240 | 15.228 | —.012 | 149 | 27.003 | 27.010 | .007 |
| 58 | 15.240 | 15.228 | —.012 | 151 | 27.002 | 27.010 | .008 |
| 60 | 15.240 | 15.228 | —.012 | 153 | 27.004 | 27.010 | .006 |
| 62 | 15.240 | 15.228 | —.012 | 155 | 27.004 | 27.011 | .007 |
| 64 | 15.240 | 15.227 | —.013 | 157 | 27.004 | 27.011 | .007 |
| 66 | 15.240 | 15.227 | —.013 | 159 | 27.004 | 27.012 | .008 |
| 68 | 15.240 | 15.227 | —.013 | 161 | 27.003 | 27.010 | .007 |
| 70 | 15.241 | 15.227 | —.014 | 166 | 31.997 | 32.006 | .009 |
| 72 | 15.241 | 15.227 | —.014 | 168 | 31.997 | 32.008 | .011 |
| 74 | 15.241 | 15.228 | —.013 | 171 | 33.997 | 34.006 | .009 |
| 76 | 15.240 | 15.228 | —.012 | 172 | 33.997 | 34.006 | .009 |
| 78 | 15.240 | 15.228 | —.012 | | | | |

*Table showing the extension, restoration, and permanent set, per inch in length, caused by the under-mentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel, 9.993 inches long and 0.645 inch diameter, taken from jacket of 11-inch breech-loading rifle No. 1.*

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0000 |
| 2,000 | .0002 | .0001 | .0002 | .0001 | .0000 | .0000 |
| 3,000 | .0003 | .0001 | .0003 | .0001 | .0000 | .0000 |
| 4,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 5,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 6,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 7,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 8,000 | .0004 | .0001 | .0003 | .0000 | .0001 | .0001 |
| 9,000 | .0005 | .0001 | .0004 | .0001 | .0001 | .0000 |
| 10,000 | .0005 | .0000 | .0004 | .0000 | .0001 | .0000 |
| 11,000 | .0006 | .0001 | .0004 | .0000 | .0002 | .0001 |
| 12,000 | .0006 | .0000 | .0004 | .0000 | .0002 | .0000 |
| 13,000 | .0006 | .0000 | .0004 | .0000 | .0002 | .0000 |
| 14,000 | .0007 | .0001 | .0005 | .0001 | .0002 | .0000 |
| 15,000 | .0008 | .0001 | .0006 | .0001 | .0002 | .0000 |
| 16,000 | .0008 | .0000 | .0006 | .0000 | .0002 | .0000 |
| 17,000 | .0013 | .0005 | .0007 | .0001 | .0006 | .0004 |
| 18,000 | .0013 | .0000 | .0007 | .0000 | .0006 | .0000 |
| 19,000 | .0013 | .0000 | .0007 | .0000 | .0006 | .0000 |
| 20,000 | .0013 | .0000 | .0007 | .0000 | .0006 | .0000 |
| 21,000 | .0014 | .0001 | .0007 | .0000 | .0007 | .0001 |
| 22,000 | .0015 | .0001 | .0007 | .0000 | .0008 | .0001 |
| 23,000 | .0022 | .0007 | .0009 | .0002 | .0013 | .0005 |
| 24,000 | .0034 | .0012 | .0007 | —.0002 | .0026 | .0013 |
| 25,000 | .0039 | .0005 | .0009 | .0002 | .0030 | .0004 |
| 26,000 | .0042 | .0003 | .0010 | .0001 | .0035 | .0005 |
| 27,000 | .0056 | .0014 | .0011 | .0001 | .0045 | .0010 |
| 28,000 | .0068 | .0012 | .0010 | —.0001 | .0048 | .0003 |
| 29,000 | .0073 | .0005 | .0012 | .0002 | .0061 | .0013 |
| 30,000 | .0084 | .0011 | .0013 | .0001 | .0071 | .0010 |
| 31,000 | .0098 | .0014 | .0014 | .0001 | .0084 | .0013 |
| 32,000 | .0106 | .0008 | .0012 | —.0002 | .0092 | .0007 |
| 33,000 | .0117 | .0011 | .0014 | .0002 | .0112 | .0010 |
| 34,000 | .0130 | .0013 | .0016 | .0002 | .0118 | .0016 |
| 35,000 | .0143 | .0013 | .0015 | —.0001 | .0128 | .0010 |
| 36,000 | .0150 | .0007 | .0016 | .0001 | .0134 | .0006 |
| 37,000 | .0170 | .0020 | .0018 | .0002 | .0152 | .0018 |
| 38,000 | .0181 | .0011 | .0013 | —.0005 | .0168 | .0016 |
| 39,000 | .0197 | .0016 | .0018 | .0005 | .0179 | .0011 |
| 40,000 | .0213 | .0016 | .0019 | .0001 | .0194 | .0015 |
| 41,000 | .0228 | .0015 | .0020 | .0001 | .0208 | .0014 |
| 42,000 | .0247 | .0019 | .0019 | —.0001 | .0228 | .0020 |
| 43,000 | .0262 | .0015 | .0021 | .0002 | .0241 | .0013 |
| 44,000 | .0289 | .0027 | .0021 | .0000 | .0268 | .0027 |
| 45,000 | .0302 | .0013 | .0019 | —.0002 | .0283 | .0015 |
| 46,000 | .0325 | .0023 | .0022 | .0003 | .0303 | .0020 |
| 47,000 | .0351 | .0026 | .0022 | .0000 | .0329 | .0026 |
| 48,000 | .0378 | .0022 | .0023 | .0501 | .0350 | .0021 |
| 49,000 | .0401 | .0028 | .0023 | .0000 | .0377 | .0027 |
| 50,000 | .0433 | .0033 | .0025 | .0002 | .0408 | .0031 |
| 51,000 | .0456 | .0023 | .0025 | .0000 | .0431 | .0023 |
| 52,000 | .0498 | .0032 | .0025 | .0000 | .0473 | .0042 |
| 53,000 | .0534 | .0036 | .0026 | .0001 | .0508 | .0035 |
| 54,000 | .0579 | .0045 | .0027 | .0001 | .0552 | .0044 |
| 55,000 | .0628 | .0049 | .0027 | .0000 | .0601 | .0049 |
| 56,000 | .0683 | .0055 | .0030 | .0003 | .0653 | .0052 |
| 57,000 | .0745 | .0062 | .0029 | —.0001 | .0716 | .0063 |
| 58,000 | .0818 | .0073 | .0030 | .0001 | .0733 | .0017 |
| 59,000 | .0891 | .0078 | .0032 | .0002 | .0759 | .0026 |
| 60,000 | .0988 | .0097 | .0030 | .0002 | .0858 | .0099 |
| 61,000 | .1123 | .0135 | .0030 | .0000 | .0893 | .0035 |
| 62,000 | .1367 | .0244 | .0035 | .0005 | .1332 | .0439 |
| 63,000 | .1673 | .0306 | .0036 | .0001 | .1637 | .0305 |
| 64,000 | Specimen broke. | | | | | |

### GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7. 8733 |
| Tensile strength, per square inch ............ pounds.. | 63, 996 |
| Elastic limit ............ pounds.. | 7, 000 |
| Extension, per inch, at elastic limit ............ inch.. | 0. 0003 |
| Extension, per inch, at rupture ............ inch.. | 0. 1673 |
| Hardness | 11. 083 |
| Original area of cross-section ............ square inch.. | 0. 32675 |
| Area after rupture ............ square inch.. | 0. 24010 |
| Position of rupture | Near center. |
| Character of fracture | Silky fibrous. |

*Table showing the extension, restoration, and permanent set per inch in length caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel* 2.995 *inches long and* 0.564 *inch diameter, taken from jacket of* 11-*inch breech-loading rifle No.* 1.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 4, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 5, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 6, 000 | . 00033 | . 00033 | . 00033 | . 00033 | . 00000 | . 00000 |
| 7, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 8, 000 | . 00066 | . 00033 | . 00066 | . 00033 | . 00000 | . 00000 |
| 9, 000 | . 00066 | . 00000 | . 00066 | . 00000 | . 00000 | . 00000 |
| 10, 000 | . 00066 | . 00000 | . 00066 | . 00000 | . 00000 | . 00000 |
| 11, 000 | . 00066 | . 00000 | . 00066 | . 00000 | . 00000 | . 00000 |
| 12, 000 | . 00066 | . 00000 | . 00066 | . 00000 | . 00000 | . 00000 |
| 13, 000 | . 00066 | . 00000 | . 00066 | . 00000 | . 00000 | . 00000 |
| 14, 000 | . 00066 | . 00000 | . 00066 | . 00000 | . 00000 | . 00000 |
| 15, 000 | . 00066 | . 00000 | . 00066 | . 00000 | . 00000 | . 00000 |
| 16, 000 | . 00100 | . 00034 | . 00100 | . 00033 | . 00000 | . 00000 |
| 17, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 18, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 19, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 20, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 21, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 22, 000 | . 00166 | . 00066 | . 00100 | . 00000 | . 00000 | . 00000 |
| 23, 000 | . 00233 | . 00067 | . 00100 | . 00000 | . 00133 | . 00133 |
| 24, 000 | . 00300 | . 00067 | . 00066 | — . 00034 | . 00233 | . 00100 |
| 25, 000 | . 00333 | . 00033 | . 00066 | . 00000 | . 00266 | . 00033 |
| 26, 000 | . 00300 | — . 00033 | . 00100 | . 00034 | . 00333 | . 00066 |
| 27, 000 | . 00500 | . 00200 | . 00166 | . 00066 | . 00400 | . 00066 |
| 28, 000 | . 00566 | . 00066 | . 00200 | . 00034 | . 00400 | . 00000 |
| 29, 000 | . 00700 | . 00134 | . 00166 | — . 00034 | . 00500 | . 00100 |
| 30, 000 | . 00766 | . 00066 | . 00133 | — . 00033 | . 00600 | . 00100 |
| 31, 000 | . 00833 | . 00067 | . 00133 | . 00000 | . 00700 | . 00100 |
| 32, 000 | . 00900 | . 00067 | . 00133 | . 00000 | . 00766 | . 00066 |
| 33, 000 | . 01033 | . 00133 | . 00133 | . 00000 | . 00900 | . 00133 |
| 34, 000 | . 01133 | . 00100 | . 00133 | . 00000 | . 01000 | . 00100 |
| 35, 000 | . 01233 | . 00100 | . 00200 | . 00067 | . 01033 | . 00033 |
| 36, 000 | . 01300 | . 00067 | . 00200 | . 00000 | . 01100 | . 00066 |
| 37, 000 | . 01400 | . 00100 | . 00200 | . 00000 | . 01233 | . 00133 |
| 38, 000 | . 01533 | . 00133 | . 00200 | . 00000 | . 01300 | . 00066 |
| 39, 000 | . 01600 | . 00067 | . 00233 | . 00033 | . 01366 | . 00066 |
| 40, 000 | . 01666 | . 00066 | . 00266 | . 00033 | . 01400 | . 00033 |
| 41, 000 | . 01766 | . 00100 | . 00333 | . 00067 | . 01433 | . 00033 |
| 42, 000 | . 01766 | . 00000 | . 00300 | —0. 00033 | . 01466 | . 00033 |
| 43, 000 | . 01833 | . 00067 | . 00200 | — . 00100 | . 01633 | . 00166 |
| 44, 000 | . 01933 | . 00100 | . 00133 | . 00066 | . 01800 | . 00166 |
| 45, 000 | . 02100 | . 00167 | . 00100 | — . 00033 | . 02000 | . 00200 |
| 46, 000 | . 02300 | . 00200 | . 00166 | . 00066 | . 02133 | . 00133 |
| 47, 000 | . 02500 | . 00200 | . 00166 | . 00000 | . 02333 | . 00200 |
| 48, 000 | . 02733 | . 00233 | . 00166 | . 00000 | . 02566 | . 00233 |
| 49, 000 | . 03033 | . 00300 | . 00300 | . 00133 | . 02733 | . 00166 |
| 50, 000 | . 03333 | . 00300 | . 00266 | —0. 00034 | . 03066 | . 00333 |
| 51, 000 | . 03600 | . 00266 | . 00266 | . 00000 | . 03333 | . 00266 |
| 52, 000 | . 03933 | . 00333 | . 00300 | . 00033 | . 03633 | . 00300 |
| 53, 000 | . 04266 | . 00333 | . 00300 | . 00000 | . 03966 | . 00333 |
| 54, 000 | . 04633 | . 00366 | . 00266 | — . 00034 | . 04366 | . 00400 |
| 55, 000 | . 05166 | . 00533 | . 00333 | . 00166 | . 04833 | . 00466 |

*Table showing the extension, restoration, and permanent set, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 56, 000 | . 05666 | . 00500 | . 00300 | — . 00033 | . 05366 | . 00533 |
| 57, 000 | . 06200 | . 00533 | . 00266 | — . 00034 | . 05933 | . 00666 |
| 58, 000 | . 06866 | . 00666 | . 00200 | — . 00066 | . 06666 | . 00733 |
| 59, 000 | . 07666 | . 00800 | . 00266 | . 00066 | . 07400 | . 00733 |
| 60, 000 | . 08666 | . 01000 | . 00333 | . 00066 | . 08333 | . 00933 |
| 61, 000 | . 09833 | . 01167 | . 00366 | . 00033 | . 09466 | . 01133 |
| 62, 000 | . 11166 | . 01333 | . 00500 | . 00133 | . 10666 | . 01200 |
| 63, 000 | . 12800 | . 01864 | . 00600 | . 00100 | . 12200 | . 01533 |
| 63, 662 | Specimen broke. | | | | | |

## GENERAL SUMMARY.

Specific gravity .......... 7.8405
Tensile strength, per square inch .......... pounds .. 63,662
Elastic limit .......... pounds .. 22,000
Extension, per inch, at elastic limit .......... inch .... 0.00166
Extension, per inch, at rupture .......... inch .... 0.128
Hardness .......... 10.370
Original area of cross-section .......... square inch .... 0.2463
Area after rupture .......... square inch .... 0.1691
Position of rupture .......... Near center.
Character of fracture .......... Mixed, fibrous, and fine crystalline.

*Table showing the extension, restoration, and permanent set per inch in length caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel* 3.005 *inches long and* 0.563 *inch diameter, taken from jacket of* 11 *inch breech-loading rifle No.* 1.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 4, 000 | . 00033 | . 00033 | . 0033 | . 00033 | . 00000 | . 00000 |
| 5, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 6, 000 | . 00033 | . 00000 | . 90033 | . 00000 | . 00000 | . 00000 |
| 7, 000 | . 00033 | . 00000 | . 00033 | . 90000 | . 00000 | . 00000 |
| 8, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 9, 000 | . 00066 | . 00033 | . 00066 | . 00033 | . 00000 | . 00000 |
| 10, 000 | . 00066 | . 00000 | . 00100 | . 00034 | . 00000 | . 00000 |
| 11, 000 | . 00100 | . 00034 | . 60100 | . 00000 | . 00000 | . 00000 |
| 12, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 13, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 14, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 15, 000 | . 00100 | . 00000 | . 00066 | — . 00034 | . 00033 | . 00033 |
| 16, 000 | . 00100 | . 00000 | . 00066 | . 00000 | . 00033 | . 00000 |
| 17, 000 | . 00100 | . 00000 | . 00066 | . 00000 | . 00033 | . 00000 |
| 18, 000 | . 00133 | . 00033 | . 00066 | . 00000 | . 00066 | . 00033 |
| 19, 000 | . 00133 | . 00000 | . 00033 | — . 00033 | . 00100 | . 00034 |
| 20, 000 | . 00166 | . 00033 | . 00066 | . 00033 | . 00100 | . 00000 |
| 21, 000 | . 00200 | . 00034 | . 00066 | . 00000 | . 00133 | . 00033 |
| 22, 000 | . 00266 | . 00066 | . 00066 | . 00000 | . 00200 | . 00067 |
| 23, 000 | . 00333 | . 00067 | . 00066 | . 00000 | . 00266 | . 00066 |
| 24, 000 | . 00333 | . 00000 | . 00066 | . 00000 | . 00266 | . 00000 |
| 25, 000 | . 00333 | . 00000 | . 00066 | . 00000 | . 00266 | . 00000 |
| 26, 000 | . 00433 | . 00100 | . 00066 | . 00000 | . 00366 | . 00100 |
| 27, 000 | . 00600 | . 00167 | . 00100 | . 00034 | . 00500 | . 00134 |
| 28, 000 | . 00633 | . 00033 | . 00066 | — . 00034 | . 00566 | . 00066 |

*Table showing the extension, restoration, and permanent set, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 29, 000 | . 00733 | . 00100 | . 00066 | . 00000 | . 00666 | . 00100 |
| 30, 000 | . 00766 | . 00033 | . 00100 | . 00034 | . 00666 | . 00000 |
| 31, 000 | . 00900 | . 00134 | . 00100 | . 00000 | . 00800 | . 00134 |
| 32, 000 | . 00933 | . 00033 | . 00100 | . 00000 | . 00833 | . 00033 |
| 33, 000 | . 00966 | . 00033 | . 00066 | — . 00034 | . 00900 | . 00067 |
| 34, 000 | . 01033 | . 00067 | . 00133 | . 00067 | . 00966 | . 00066 |
| 35, 000 | . 01033 | . 00000 | . 00100 | — . 00033 | . 00966 | . 00000 |
| 36, 000 | . 01200 | . 00167 | . 00100 | . 00000 | . 01100 | . 00133 |
| 37, 000 | . 01566 | . 00366 | . 00133 | . 00033 | . 01433 | . 00333 |
| 38, 000 | . 01566 | . 00000 | . 00133 | . 00000 | . 01433 | . 00000 |
| 39, 000 | . 01733 | . 00167 | . 00166 | . 00033 | . 01566 | . 00133 |
| 40, 000 | . 01833 | . 00100 | . 00133 | — . 00033 | . 01700 | . 00134 |
| 41, 000 | . 02200 | . 00367 | . 00200 | . 00067 | . 02000 | . 00300 |
| 42, 000 | . 02433 | . 00233 | . 00233 | . 00033 | . 02200 | . 00200 |
| 43, 000 | . 02600 | . 00167 | . 00200 | — . 00033 | . 02400 | . 00200 |
| 44, 000 | . 02900 | . 00300 | . 00200 | . 00000 | . 02700 | . 00300 |
| 45, 000 | . 02966 | . 00066 | . 00266 | . 00066 | . 02700 | . 00000 |
| 46, 000 | . 03100 | . 00134 | . 00233 | — . 00033 | . 02933 | . 00233 |
| 47, 000 | . 03100 | . 00000 | . 00200 | — . 00033 | . 02966 | . 00033 |
| 48, 000 | . 03433 | . 00333 | . 00200 | . 00000 | . 03233 | . 00267 |
| 49, 000 | . 03600 | . 00167 | . 00266 | . 00066 | . 03333 | . 00100 |
| 50, 000 | . 03800 | . 00200 | . 00233 | — . 00033 | . 03566 | . 00233 |
| 51, 000 | . 03833 | . 00033 | . 00233 | . 00000 | . 03600 | . 00034 |
| 52, 000 | . 04366 | . 00533 | . 00266 | . 00033 | . 04100 | . 00500 |
| 53, 000 | . 04833 | . 00467 | . 00233 | — . 00033 | . 04600 | . 00500 |
| 54, 000 | . 05300 | . 00467 | . 00266 | . 00033 | . 05033 | . 00433 |
| 55, 000 | . 05833 | . 00533 | . 00300 | . 00034 | . 05533 | . 00500 |
| 56, 000 | . 05866 | . 00033 | . 00300 | . 00000 | . 05566 | . 00033 |
| 57, 000 | . 06166 | . 00300 | . 00300 | . 00000 | . 05866 | . 00300 |
| 58, 000 | . 06833 | . 00667 | . 00300 | . 00000 | . 06533 | . 00667 |
| 59, 000 | . 07766 | . 00933 | . 00333 | . 00033 | . 07433 | . 00900 |
| 60, 000 | . 07833 | . 00067 | . 00300 | — . 00033 | . 07533 | . 00100 |
| 61, 000 | . 08100 | . 00267 | . 00466 | . 00166 | . 07633 | . 00100 |
| 62, 000 | . 08366 | . 00266 | . 00333 | — . 00133 | . 08033 | . 00400 |
| 63, 000 | . 09133 | . 00767 | . 00300 | — . 00033 | . 08866 | . 00833 |
| 64, 000 | . 10333 | . 01200 | . 00333 | . 00033 | . 10000 | . 00134 |
| 65, 000 | . 11500 | . 01167 | . 00366 | . 00033 | . 11133 | . 01133 |
| 66, 000 | . 12900 | . 01400 | . 00333 | — . 00033 | . 12566 | . 01433 |
| 67, 000 | Specimen broke. | | .............. | .............. | .............. | .............. |

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7. 8764 |
| Tensile strength, per square inch ........ pounds.. | 67, 024 |
| Elastic limit ........ pounds.. | 14, 000 |
| Extension per inch, at elastic limit ........ inch.... | 0. 00100 |
| Extension per inch, at rupture ........ inch.... | 0. 129 |
| Hardness | 11. 862 |
| Original area of cross-section ........ square inch.... | 0. 24894 |
| Area after rupture ........ square inch.... | 0. 15344 |
| Position of rupture | Below centre. |
| Character of fracture | Mixed, fibrous, and fine crystalline. |

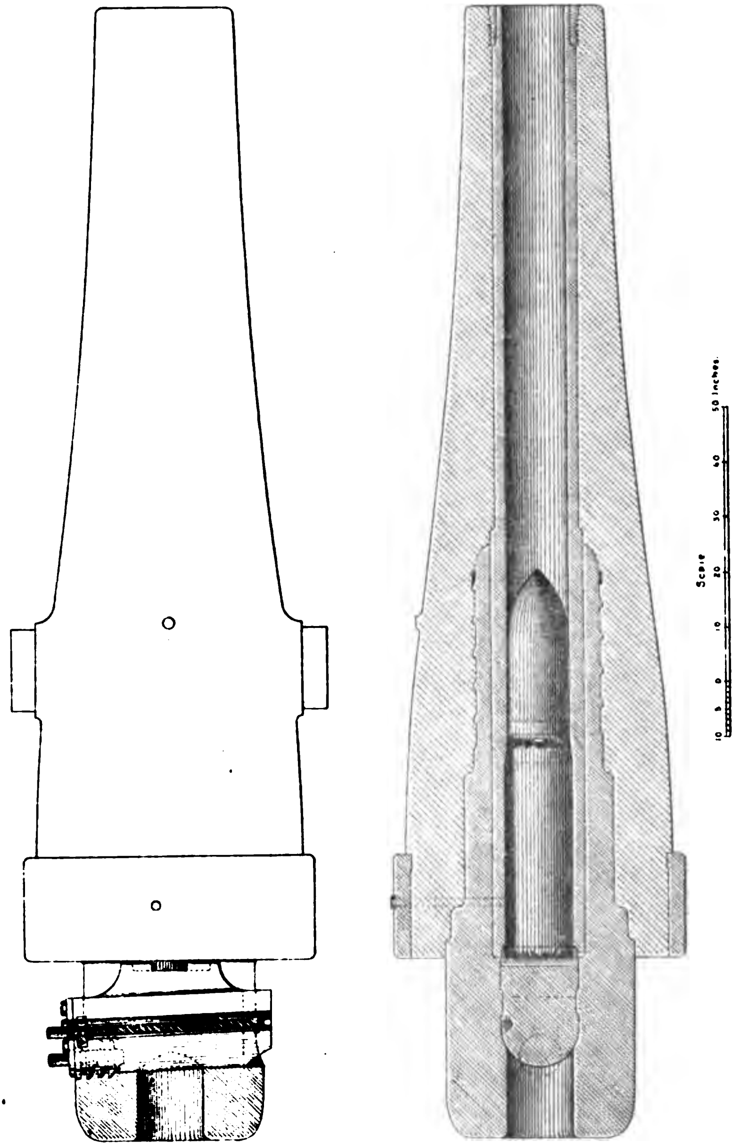
*Table showing the extension, restoration, and permanent set, per inch in length, caused by the under-mentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel,* 10.025 *inches long and* 0.650 *inch diameter, taken from jacket of* 11-*inch breech-loading rifle No.* 1.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 3,000 | .0001 | .0001 | .0001 | .0001 | .0000 | .0000 |
| 4,000 | .0001 | .0000 | .0001 | .0000 | .0000 | .0000 |
| 5,000 | .0002 | .0001 | .0002 | .0001 | .0000 | .0000 |
| 6,000 | .0002 | .0000 | .0002 | .0000 | .0000 | .0000 |
| 7,000 | .0003 | .0001 | .0003 | .0001 | .0000 | .0000 |
| 8,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 9,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 10,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 11,000 | .0004 | .0001 | .0004 | .0001 | .0000 | .0000 |
| 12,000 | .0004 | .0000 | .0004 | .0000 | .0000 | .0000 |
| 13,000 | .0005 | .0001 | .0005 | .0001 | .0000 | .0000 |
| 14,000 | .0005 | .0000 | .0005 | .0000 | .0000 | .0000 |
| 15,000 | .0005 | .0000 | .0005 | .0000 | .0000 | .0000 |
| 16,000 | .0006 | .0001 | .0006 | .0001 | .0000 | .0000 |
| 17,000 | .0007 | .0001 | .0006 | .0000 | .0001 | .0001 |
| 18,000 | .0007 | .0000 | .0006 | .0000 | .0001 | .0000 |
| 19,000 | .0007 | .0000 | .0006 | .0000 | .0001 | .0000 |
| 20,000 | .0008 | .0001 | .0007 | .0001 | .0001 | .0000 |
| 21,000 | .0009 | .0001 | .0007 | .0000 | .0002 | .0001 |
| 22,000 | .0011 | .0002 | .0008 | .0001 | .0003 | .0001 |
| 23,000 | .0013 | .0002 | .0008 | .0000 | .0005 | .0002 |
| 24,000 | .0015 | .0002 | .0008 | .0000 | .0007 | .0002 |
| 25,000 | .0018 | .0003 | .0008 | .0000 | .0010 | .0003 |
| 26,000 | .0023 | .0005 | .0010 | .0002 | .0013 | .0003 |
| 27,000 | .0033 | .0010 | .0010 | .0000 | .0023 | .0010 |
| 28,000 | .0038 | .0005 | .0010 | .0000 | .0028 | .0005 |
| 29,000 | .0047 | .0009 | .0012 | .0002 | .0035 | .0007 |
| 30,000 | .0053 | .0006 | .0010 | —.0002 | .0043 | .0008 |
| 31,000 | .0063 | .0010 | .0010 | .0000 | .0053 | .0010 |
| 32,000 | .0073 | .0010 | .0012 | .0002 | .0061 | .0008 |
| 33,000 | .0083 | .0010 | .0013 | .0001 | .0070 | .0009 |
| 34,000 | .0093 | .0010 | .0014 | .0001 | .0079 | .0009 |
| 35,000 | .0103 | .0010 | .0014 | .0000 | .0089 | .0010 |
| 36,000 | .0113 | .0010 | .0015 | .0001 | .0098 | .0009 |
| 37,000 | .0126 | .0013 | .0016 | .0001 | .0110 | .0012 |
| 38,000 | .0134 | .0008 | .0015 | —.0001 | .0119 | .0009 |
| 39,000 | .0150 | .0016 | .0017 | .0002 | .0133 | .0014 |
| 40,000 | .0162 | .0012 | .0018 | .0001 | .0144 | .0011 |
| 41,000 | .0175 | .0013 | .0019 | .0001 | .0156 | .0012 |
| 42,000 | .0188 | .0013 | .0018 | —.0001 | .0170 | .0014 |
| 43,000 | .0200 | .0012 | .0019 | .0001 | .0181 | .0011 |
| 44,000 | .0216 | .0016 | .0019 | .0000 | .0197 | .0016 |
| 45,000 | .0231 | .0015 | .0020 | .0001 | .0211 | .0014 |
| 46,000 | .0253 | .0022 | .0020 | .0001 | .0233 | .0022 |
| 47,000 | .0267 | .0024 | .0021 | .0001 | .0246 | .0013 |
| 48,000 | .0287 | .0020 | .0021 | .0000 | .0266 | .0020 |
| 49,000 | .0305 | .0018 | .0022 | .0001 | .0283 | .0017 |
| 50,000 | .0325 | .0020 | .0023 | .0001 | .0302 | .0019 |
| 51,000 | .0350 | .0025 | .0024 | .0001 | .0320 | .0018 |
| 52,000 | .0373 | .0023 | .0025 | .0001 | .0348 | .0028 |
| 53,000 | .0399 | .0026 | .0026 | .0001 | .0373 | .0025 |
| 54,000 | .0425 | .0026 | .0026 | .0000 | .0399 | .0026 |
| 55,000 | .0451 | .0026 | .0022 | —.0004 | .0429 | .0030 |
| 56,000 | .0495 | .0044 | .0027 | .0005 | .0468 | .0039 |
| 57,000 | Specimen breaks in shoulder. | | | | | |

GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7.8511 |
| Tensile strength, per square inch, under gradually increasing strains ... pounds.. | 57,000 |
| Elastic limit ... pounds.. | 16,000 |
| Extension, per inch, at elastic limit ... inch . | 0.0006 |
| Extension, per inch, at rupture ... inch.. | 0.0495 |
| Hardness | 13.018 |
| Original area of cross-section ... square inch.. | 0.3318 |
| Area after rupture ... square inch.. | |
| Position of rupture | In shoulder. |
| Character of fracture | Sharp crystalline. |

11 INCH B.L. CHAMBERED RIFLE.




Appendix 87h. 1881.

# APPENDIX 37*a*.

## CONSTRUCTION REPORT OF THE 11-INCH CHAMBERED MUZZLE-LOADING RIFLE, CONVERTED FROM A 15-INCH SMOOTH-BORE RODMAN GUN.

(One plate.)

### PRELIMINARY REMARKS.

The presence of the chamber is the characteristic feature which distinguishes this rifle from the 11-inch muzzle-loading converted rifle described in the report of the Chief of Ordnance for 1879; but the shoulder of the jacket which existed in that gun has been dispensed with in the new construction, and the diameters of the tube and jacket have been necessarily increased, and the dimensions of the breech-cup slightly changed.

### DESCRIPTION OF GUN.

Plate I represents in section the principal details, which are as follows: The original 15-inch cast-iron smooth-bore, bored and counterbored to receive the lining; the tube of coiled wrought iron (welded), closed at bottom by a wrought-iron cup; the hollow wrought-iron jacket shrunk upon the rear of the tube, and projecting in rear of it to the face of the breech; the cast-iron breech plug and its wrought-iron sleeve; the muzzle collar; the securing pins, and the gas escape.

### RIFLING.

The rifling of the gun consists of 19 lands and grooves of equal width.

| | |
|---|---|
| Width of lands | 0.909 |
| Width of grooves | 0.909 |
| Depth of grooves | 0.09 |

Twist uniform, one turn in 60 feet.
The rifling stops at the mouth of the chamber.

### CHAMBER.

| | Inches. |
|---|---|
| Diameter of chamber | 12.0 |
| Length of cylindrical part | 29.75 |
| Length of bevel | 4.00 |
| Depth of breech-cup | 4.50 |
| Total length of chamber | 38.25 |

### VENTING.

The old vent is closed by a wrought-iron screw plug, and a new vent is made at a distance of 9.5 inches from the bottom of the bore and 2.5 inches to the left of the vertical plane through the axis of the bore.

### TRUNNIONS.

For the purpose of correcting muzzle preponderance, the axis of the trunnions is moved 0.5 inch toward the muzzle by reducing the diameters eccentrically from 15 to 14 inches.

## FABRICATION.

The tube was manufactured and work of conversion performed at the West Point foundry, and the gun selected for the conversion was 15-inch Rodman smooth-bore No. 82, manufactured at the South Boston foundry in 1865. The tube was made of Ulster tube iron, the inner tube and breech cup of "A" quality, and the jacket, sleeve, and muzzle collar of "B" quality.

The following results were obtained by mechanical tests of specimens cut with the fiber from the bars used:

| Specimens from— | Length beween shoulders. | Area of cross-section. | Tenacity per square inch. | Elastic limit. | Extension per inch at rupture. | Remarks. |
|---|---|---|---|---|---|---|
| | *In.* | *Sq. in.* | *Lbs.* | *Lbs.* | *Inch.* | |
| 4″ × 3″.35 hexagonal bar (mean of three results) | 3.00 | 0.2497 | 48,167 | 25,333 | 0.274 | "A" quality. |
| 3″ square bar | 3.00 | 0.255 | 48,500 | 25,000 | 0.306 | Do. |
| 2¼″ square bar (mean of two results) | 3.00 | 0.253 | 49,000 | 25,000 | 0.314 | Do. |
| do. do. | 3.00 | 0.252 | 51,000 | 26,000 | 0.286 | "B" quality. |
| 5¼″ square bar | 3.00 | 0.253 | 48,500 | 24,000 | 0.277 | Do. |

The tube was made in six sections, as described in the construction report, of 11-inch converted muzzle-loading rifle No. 1, report of the Chief of Ordnance for 1879, and the other details of construction were identical with those described in that report, except that the tube was chambered before the breech cup was screwed into place.

## INSPECTION.

The tube and jacket were proved with a water pressure of 180 pounds to the square inch; careful inspections were made of every detail incident to the construction; and the gun, after completion, finally inspected, accepted as satisfactory, and shipped to Sandy Hook for powder proof.

### *Principal dimensions.*

| Subject of measurement. | Dimensions. |
|---|---|
| Total length of inner tube ........ inches | 165.7 |
| Length of jacket over tube ........ do | 59.875 |
| Interior diameter of jacket over tube ........ do | 15.5 |
| Diameter of tube under jacket ........ do | 15.503 |
| Shrinkage ........ do | .003 |
| Length of jacket in rear of tube ........ do | 25.5 |
| Total length of complete tube ........ do | 191.2 |
| Total length of bore of casing ........ do | 189.2 |
| Depth of wrought-iron cup at bottom of tube ........ do | 4.5 |
| Thickness at bottom of wrought-iron cup ........ do | 4.0 |
| Diameter of interior of cup at top ........ do | 9.8 |
| Diameter of interior of cup at bottom ........ do | 6.25 |
| Diameter of finished tube from end of screw-thread to first shoulder ........ do | 19.498 |
| Diameter of bore of casing from end of screw-thread to first shoulder ........ do | 19.5 |
| Corresponding play ........ do | .002 |
| Diameter of finished tube from first shoulder to second shoulder ........ do | 16.48 |
| Diameter of bore of casing from first shoulder to second shoulder ........ do | 16.49 |
| Corresponding play ........ do | .01 |
| Diameter of finished tube from second shoulder to neck ........ do | 15.214 |
| Corresponding diameter of casing ........ do | 15.216 |
| Corresponding play ........ do | .002 |
| Length of chase (from neck to second shoulder) ........ do | 87.217 |
| Length of first reinforce (from second to first shoulder) ........ do | 11.125 |
| Length of second reinforce (from first shoulder to screw-thread) ........ do | 63.625 |

*Principal dimensions*—Continued.

| Subject of measurement. | Dimensions. |
|---|---|
| Length of screw on jacket ........ inches.. | 19.75 |
| Pitch of screw on jacket ........ do.... | 3.7 |
| Diameter of jacket across threads ........ do.... | 20.3 |
| Corresponding diameter of casing ........ do.... | 20.31 |
| Corresponding play ........ do.... | .01 |
| Diameter of cast-iron breech plug across threads ........ do.... | 6.5 |
| Length of cast-iron breech plug ........ do.... | 35.75 |
| Diameter of wrought-iron sleeve for breech plug across threads ........ do.... | 12.4 |
| Length of wrought-iron sleeve for breech plug ........ do.... | 25.5 |
| Length of neck of tube ........ do.... | 7.0 |
| Length of muzzle collar ........ do.... | 7.0 |
| Length of recess in casing ........ do.... | 7.4 |
| Diameter of tube over neck ........ do.... | 13.84 |
| Interior diameter of muzzle collar ........ do.... | 13.85 |
| Corresponding play ........ do.... | .01 |
| Diameter of muzzle collar across threads ........ do.... | 16.75 |
| Diameter of recess in casing ........ do.... | 16.76 |
| Play between collar and casing ........ do.... | .01 |
| Thickness on collar ........ do.... | 1.45 |
| Pitch of thread on collar ........ do.... | .75 |
| Radius of curve at bottom of bore of jacket ........ do.... | .62 |
| Radius of curve at bottom of tube ........ do.... | .75 |
| Diameter of gas channel through casing ........ do.... | .2 |
| Distance of interior orifice below axis of bore ........ do.... | 7.5 |
| Distance of exterior orifice from tangent to base of gun ........ do.... | 12.0 |
| Length of bore ........ do.... | 161.7 |
| Length of rifled portion of bore ........ do.... | 123.45 |
| Diameter of bore across lands ........ do.... | 11.0 |
| Number of grooves and lands ........ do.... | 19.0 |
| Width of grooves ........ do.... | .908 |
| Width of lands ........ do.... | .9105 |
| Depth of grooves ........ do.... | .09 |
| Pitch of rifling, one turn in ........ feet.. | 59.886 |
| Diameter of chamber ........ inches.. | 12.0 |
| Length, cylindrical part of chamber ........ do.... | 29.75 |
| Length of bevel ........ do.... | 4.0 |
| Depth of breech cup ........ do.... | 4.5 |
| Total length of chamber ........ do.... | 38.25 |
| Diameter of vent ........ do.... | .20 |
| Diameter of vent bushing ........ do.... | 1.0 |
| Axis of vent from bottom of bore ........ do.... | 9.5 |
| Axis of vent from vertical plane through axis of bore (to the left) ........ do.... | 2.5 |
| Diameter of trunnions ........ do.... | 14.0 |
| Diameter of securing pins ........ do.... | 1.5 |
| Distance of first securing pin from muzzle (on the left) ........ do.... | 17.5 |
| Distance of second securing pin from muzzle (on the right) ........ do.... | 36.0 |
| Distance of third securing pin from muzzle (from above) ........ do.... | 58.5 |
| Distance of fourth securing pin from muzzle (from below) ........ do.... | 77.0 |
| Finished weight of rifle ........ pounds.. | 54,560 |

***Relative diameters of the interior of the cast-iron casing and exterior of the united tube and jacket.** 11-**inch muzzle-loading chambered rifle.***

FROM MUZZLE COLLAR TO SHOULDER ON TUBE.

| Distance from muzzle. | Diameter of bore of casing. | Exterior diameter of tube. | Difference. | Distance from muzzle. | Diameter of bore of casing. | Exterior diameter of tube. | Difference. |
|---|---|---|---|---|---|---|---|
| *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 93 | 15.219 | 15.218 | 0.001 | 49 | 15.204 | 15.200 | 0.004 |
| 91 | 15.219 | 15.218 | .001 | 47 | 15.204 | 15.200 | .004 |
| 89 | 15.220 | 15.219 | .001 | 45 | 15.204 | 15.200 | .004 |
| 87 | 15.219 | 15.216 | .003 | 43 | 15.204 | 15.200 | .004 |
| 85 | 15.217 | 15.212 | .005 | 41 | 15.204 | 15.200 | .004 |
| 83 | 15.215 | 15.213 | .002 | 39 | 15.204 | 15.200 | .004 |
| 81 | 15.217 | 15.215 | .002 | 37 | 15.205 | 15.200 | .005 |
| 79 | 15.218 | 15.214 | .004 | 35 | 15.204 | 15.200 | .004 |
| 77 | 15.218 | 15.214 | .004 | 33 | 15.205 | 15.200 | .005 |
| 75 | 15.217 | 15.214 | .003 | 31 | 15.205 | 15.200 | .005 |
| 73 | 15.216 | 15.214 | .002 | 29 | 15.206 | 15.200 | .006 |

*Relative diameters of the interior of the cast-iron casing, &c.*—Continued.

| Distance from muzzle. | Diameter of bore of casing. | Exterior diameter of tube. | Difference. | Distance from muzzle. | Diameter of bore of casing. | Exterior diameter of tube. | Difference. |
|---|---|---|---|---|---|---|---|
| *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 71 | 15.216 | 15.213 | .003 | 27 | 15.206 | 15.200 | .006 |
| 69 | 15.215 | 15.211 | .004 | 25 | 15.207 | 15.200 | .007 |
| 67 | 15.208 | 15.207 | .001 | 23 | 15.208 | 15.200 | .008 |
| 65 | 15.205 | 15.205 | .000 | 21 | 15.208 | 15.200 | .008 |
| 63 | 15.206 | 15.204 | .002 | 19 | 15.211 | 15.200 | .011 |
| 61 | 15.206 | 15.203 | .003 | 17 | 15.212 | 15.200 | .012 |
| 59 | 15.205 | 15.203 | .002 | 15 | 15.212 | 15.200 | .012 |
| 57 | 15.205 | 15.203 | .002 | 13 | 15.212 | 15.200 | .013 |
| 55 | 15.205 | 15.203 | .002 | 11 | 15.212 | 15.200 | .012 |
| 53 | 15.204 | 15.203 | .091 | 9 | 15.212 | 15.200 | .012 |
| 51 | 15.204 | 15.201 | .003 | 7 | 15.212 | 15.200 | .012 |

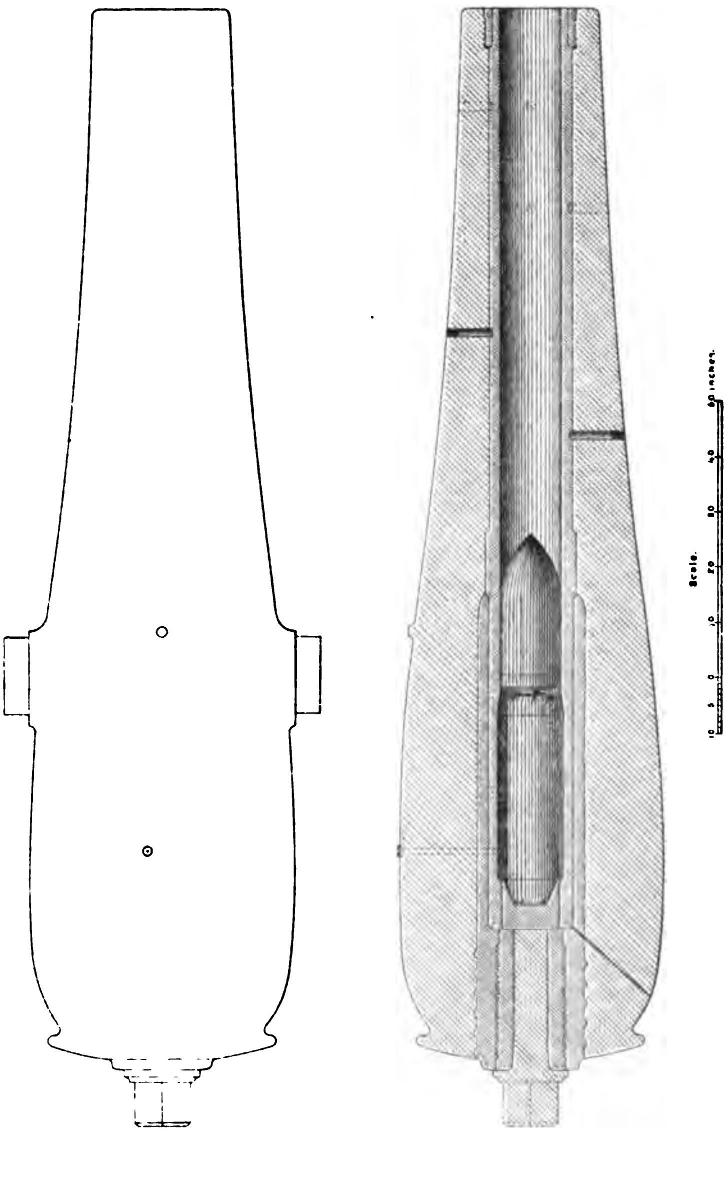
FROM SHOULDER ON TUBE TO JACKET.

| Distance from breech. | Diameter of bore of casing. | Exterior diameter of tube. | Difference. | Distance from breech. | Diameter of bore of casing. | Exterior diameter of tube. | Difference. |
|---|---|---|---|---|---|---|---|
| *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 94 | 16.490 | 16.499 | 0.011 | 87 | 16.490 | 16.480 | 0.010 |
| 91 | 16.490 | 16.479 | .011 | 84 | 16.490 | 16.481 | .009 |

FROM FRONT OF JACKET TO SCREW THREAD.

| Distance from breech. | Diameter of bore of casing. | Exterior diameter of tube. | Difference. | Distance from breech. | Diameter of bore of casing. | Exterior diameter of tube. | Difference. |
|---|---|---|---|---|---|---|---|
| *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 79 | 19.498 | 19.496 | 0.002 | 49 | 19.500 | 19.498 | 0.002 |
| 78 | 19.498 | 19.496 | .002 | 48 | 19.500 | 19.498 | .002 |
| 77 | 19.498 | 19.496 | .002 | 47 | 19.501 | 19.498 | .003 |
| 76 | 19.498 | 19.496 | .002 | 46 | 19.501 | 19.498 | .003 |
| 75 | 19.498 | 19.496 | .002 | 45 | 19.500 | 19.498 | .002 |
| 74 | 19.498 | 19.496 | .002 | 44 | 19.501 | 19.498 | .003 |
| 73 | 19.498 | 19.496 | .002 | 43 | 19.501 | 19.498 | .003 |
| 72 | 19.499 | 19.496 | .003 | 42 | 19.500 | 19.498 | .002 |
| 71 | 19.498 | 19.496 | .002 | 41 | 19.501 | 19.498 | .003 |
| 70 | 19.498 | 19.496 | .002 | 40 | 19.500 | 19.498 | .002 |
| 69 | 19.498 | 19.496 | .002 | 39 | 19.500 | 19.498 | .002 |
| 68 | 19.499 | 19.496 | .003 | 38 | 19.500 | 19.498 | .002 |
| 67 | 19.499 | 19.496 | .003 | 37 | 19.501 | 19.498 | .003 |
| 66 | 19.499 | 19.496 | .003 | 36 | 19.501 | 19.498 | .003 |
| 65 | 19.499 | 19.497 | .002 | 35 | 19.501 | 19.498 | .003 |
| 64 | 19.499 | 19.497 | .002 | 34 | 19.501 | 19.498 | .003 |
| 63 | 19.499 | 19.497 | .002 | 33 | 19.501 | 19.498 | .003 |
| 62 | 16.499 | 19.497 | .002 | 32 | 19.501 | 19.498 | .003 |
| 61 | 19.499 | 19.497 | .002 | 31 | 19.501 | 19.498 | .003 |
| 60 | 19.499 | 19.497 | .002 | 30 | 19.501 | 19.498 | .003 |
| 59 | 19.499 | 19.497 | .002 | 29 | 19.502 | 19.498 | .904 |
| 58 | 19.499 | 19.497 | .001 | 28 | 19.502 | 19.498 | .004 |
| 57 | 19.499 | 19.497 | .002 | 27 | 19.503 | 19.498 | .005 |
| 56 | 19.499 | 19.497 | .002 | 26 | 19.503 | 19.498 | .005 |
| 55 | 19.499 | 19.497 | .002 | 25 | 19.502 | 19.498 | .004 |
| 54 | 19.499 | 19.497 | .002 | 24 | 19.502 | 19.498 | .004 |
| 53 | 19.499 | 19.497 | .002 | 23 | 19.503 | 19.498 | .005 |
| 53 | 19.496 | 19.497 | .002 | 22 | 19.503 | 19.498 | .005 |
| 51 | 19.499 | 19.497 | .002 | 21 | 19.503 | 19.498 | .005 |
| 50 | 19.499 | 19.497 | .002 | | | | |

11 INCH M.L. CHAMBERED RIFLE.



## APPENDIX 37*b*.

**CONSTRUCTION REPORT OF AN 8-INCH BREECH-LOADING CHAMBERED RIFLE, CONVERTED FROM A 10-INCH RODMAN SMOOTH-BORE, BY LINING WITH A STEEL JACKETED COILED WROUGHT-IRON TUBE, INSERTED FROM THE BREECH; JACKET OF THE TUBE BEING PROLONGED TO THE REAR AND ADAPTED FOR THE INSERTION OF THE ROUND-WEDGE FERMETURE.**

(One plate.)

This gun was constructed in general like that described in the report of Chief of Ordnance for 1878, p. 357, *et seq.*

### RIFLING, CHAMBERING, AND VENTING.

The rifling consists of 40 grooves and lands.

| | Inch. |
|---|---|
| Depth of grooves | 0.06 |
| Width of grooves | 0.41886 |
| Width of lands | 0.20943 |

Twist, uniform; one turn in 30 feet.

The powder chamber is 26″.15 long. It is cylindrical in shape, 9″ in diameter for a distance of 22″.15 from the breech, and terminates in a conic frustum 4″ long, with a least diameter of 8″.19. In front of the chamber is a seat for the base of the projectile 1″.45 long and 8″.19 in diameter. A conic frustum 1″.6 long connects the seat with the surface of the lands. The axis of the vent, 7″ from the breech of casing, is perpendicular to the axis of the bore and 2″.5 to its left.

### FABRICATION.

The casing of the gun was made from a 10″ Rodman smooth-bore. The conversion was effected at the South Boston foundry. The tube was made at West Point foundry of Ulster tube iron in four sections. The bars for the two middle sections were 2″.625 square, those for the end sections were 2″.5 square. The sections were butt-welded together, bored up to 8″ and turned down on the exterior to a diameter slightly in excess of that required for the finished tube. Specimens of the iron used were tested and gave the following characteristics as a mean of four results:

| | |
|---|---|
| Tenacity | 49,250 lbs. |
| Elastic limit | 26,750 lbs. |
| Elongation per inch, at rupture | 0″.307 |
| Length of specimens between shoulders | 3″.000 |
| Original area of cross-section | 0″.250 |

The breech-receiver, block, and band were made of English steel, received from Firth & Co., of Sheffield. The receiver and band were oil-tempered.

To prepare the casing for the tube it was bored up to 11″, recessed to

fit the muzzle collar, and cut off at the breech to a length of 123″.25. It was then counterbored as follows:

For 3″.5 from the breech to 22″.
For 10″ additional to 20″.
For 4″.5 additional to 17″.4.
For 21″ additional to 16″.6.
For 12″.5 additional to 12″.6.

The end of each counterbore was rounded off to form a suitable shoulder, and a thread 0″.4 deep was cut in the 16″.6 diameter. The exterior was then turned down to receive the breech band.

The completion of the other parts, and the assemblage of the components of the gun were effected as described in the report for 1878, previously referred to.

### INSPECTION.

The workmanship and finish of the gun were good in every respect.

#### PRINCIPAL DIMENSIONS.

| | Inches. |
|---|---|
| Total length of gun | 147.26 |
| Length of cast-iron casing | 123.25 |
| Length of wrought-iron tube | 123.25 |
| Length of steel jacket | 64 |
| Length of breech band | 15 |
| Exterior diameter of breech band | 35.7 |
| Interior diameter of breech band | 30.991 |
| Exterior diameter of casing under breech band | 31.020 |
| Length of neck of tube | 5.75 |
| Length of muzzle collar | 5.75 |
| Diameter of neck of tube | 9.98 |
| Interior diameter of muzzle collar | 9.987 |
| Length of recess for muzzle collar | 5.970 |
| Diameter of recess for muzzle collar | 11.748 |
| Diameter of muzzle collar | 11.730 |
| Length of rifled portion of bore | 95.57 |
| Length of cylindrical part of chamber | 22.15 |
| Length of conical part of chamber | 4 |
| Length of chamber, total | 26.15 |
| Length of seat for base of shot | 1.45 |
| Diameter of bore across lands | 8 |
| Diameter of cylindrical part of chamber | 9 |
| Least diameter of conical part of chamber | 8.19 |
| Diameter of seat for base of shot | 8.19 |
| Width of lands | 0.20943 |
| Width of grooves | 0.41886 |
| Depth of rifling | 0.06 |
| Twist of rifling, one turn in | 360 |
| Length of breech block | 23.5 |
| Width of breech block | 11 |
| Thickness through center | 13.5 |
| Width of slot for breech block | 11.05 |
| Length of translating screw | 25.5 |
| Diameter of translating screw across threads | 1.506 |
| Length of locking nut | 5.75 |
| Diameter of locking nut | 5.75 |

| | Lbs. |
|---|---|
| Weight of gun | 17,029 |
| Preponderance | 308 |

*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel, 7 inches long and 0.651 inch diameter, taken from breech block for 8-inch breech-loading chambered rifle.*

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 3,000 | .0001 | .0001 | .0001 | .0001 | .0000 | .0000 |
| 4,000 | .0001 | .0000 | .0001 | .0000 | .0000 | .0000 |
| 5,000 | .0003 | .0002 | .0003 | .0002 | .0000 | .0000 |
| 6,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 7,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 8,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 9,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 10,000 | .0004 | .0001 | .0004 | .0001 | .0000 | .0000 |
| 11,000 | .0004 | .0000 | .0004 | .0000 | .0000 | .0000 |
| 12,000 | .0004 | .0000 | .0004 | .0000 | .0000 | .0000 |
| 13,000 | .0004 | .0000 | .0004 | .0000 | .0000 | .0000 |
| 14,000 | .0005 | .0001 | .0005 | .0001 | .0000 | .0000 |
| 15,000 | .0005 | .0000 | .0005 | .0000 | .0000 | .0000 |
| 16,000 | .0005 | .0000 | .0005 | .0000 | .0000 | .0000 |
| 17,000 | .0006 | .0001 | .0006 | .0001 | .0000 | .0000 |
| 18,000 | .0007 | .0001 | .0007 | .0001 | .0000 | .0000 |
| 19,000 | .0007 | .0000 | .0007 | .0000 | .0000 | .0000 |
| 20,000 | .0008 | .0001 | .0008 | .0001 | .0000 | .0000 |
| 21,000 | .0010 | .0002 | .0006 | −.0002 | .0004 | .0004 |
| 22,000 | .0014 | .0004 | .0006 | .0000 | .0008 | .0004 |
| 23,000 | .0017 | .0003 | .0006 | .0000 | .0011 | .0003 |
| 24,000 | .0021 | .0004 | .0007 | .0001 | .0014 | .0003 |
| 25,000 | .0028 | .0007 | .0008 | .0001 | .0020 | .0006 |
| 26,000 | .0033 | .0005 | .0008 | .0000 | .0025 | .0005 |
| 27,000 | .0038 | .0005 | .0007 | −.0001 | .0031 | .0006 |
| 28,000 | .0045 | .0007 | .0010 | .0003 | .0035 | .0004 |
| 29,000 | .0053 | .0008 | .0010 | .0000 | .0043 | .0008 |
| 30,000 | .0058 | .0005 | .0010 | .0000 | .0048 | .0005 |
| 31,000 | .0071 | .0613 | .0014 | −.0004 | .0057 | .0009 |
| 32,000 | .0078 | .0007 | .0010 | .0004 | .0068 | .0011 |
| 33,000 | .0084 | .0006 | .0013 | .0003 | .0071 | .0003 |
| 34,000 | .0093 | .0009 | .0013 | .0000 | .0080 | .0009 |
| 35,000 | .0103 | .0010 | .0013 | .0000 | .0090 | .0010 |
| 36,000 | .0114 | .0011 | .0013 | .0000 | .0101 | .0011 |
| 37,000 | .0130 | .0016 | .0015 | .0002 | .0115 | .0014 |
| 38,000 | .0153 | .0023 | .0018 | .0003 | .0135 | .0020 |
| 39,000 | .0161 | .0008 | .0016 | −.0002 | .0145 | .0010 |
| 40,000 | .0171 | .0010 | .0017 | .0001 | .0154 | .0009 |
| 41,000 | .0180 | .0009 | .0016 | −.0001 | .0164 | .0010 |
| 42,000 | .0184 | .0004 | .0009 | −.0007 | .0175 | .0011 |
| 43,000 | .0208 | .0024 | .0018 | .0009 | .0190 | .0015 |
| 44,000 | .0221 | .0013 | .0018 | .0000 | .0203 | .0013 |
| 45,000 | .0234 | .0013 | .0020 | .0002 | .0214 | .0011 |
| 46,000 | .0250 | .0016 | .0022 | .0002 | .0228 | .0014 |
| 47,000 | .0265 | .0015 | .0020 | −.0002 | .0245 | .0017 |
| 48,000 | .0281 | .0016 | .0020 | .0000 | .0261 | .0016 |
| 49,000 | .0300 | .0019 | .0023 | .0003 | .0277 | .0016 |
| 50,000 | .0321 | .0021 | .0024 | .0001 | .0297 | .0020 |
| 51,000 | .0338 | .0017 | .0023 | −.0001 | .0315 | .0018 |
| 52,000 | .0363 | .0025 | .0023 | .0000 | .0340 | .0025 |
| 53,000 | .0387 | .0024 | .0024 | .0001 | .0363 | .0023 |
| 54,000 | .0414 | .0027 | .0026 | .0002 | .0388 | .0025 |
| 55,000 | .0440 | .0026 | .0026 | .0000 | .0414 | .0026 |
| 56,000 | .0467 | .0027 | .0027 | .0001 | .0440 | .0026 |
| 57,000 | .0507 | .0040 | .0029 | .0002 | .0478 | .0038 |
| 58,000 | .0550 | .0043 | .0030 | .0001 | .0520 | .0042 |
| 59,000 | .0577 | .0027 | .0030 | .0000 | .0547 | .0027 |
| 60,000 | .0633 | .0056 | .0029 | −.0001 | .0604 | .0057 |
| 61,000 | .0701 | .0068 | .0021 | −.0008 | .0680 | .0076 |
| 62,000 | .0771 | .0070 | .0031 | .0010 | .0740 | .0060 |
| 63,000 | .0854 | .0083 | .0033 | .0002 | .0821 | .0081 |
| 64,000 | .0950 | .0096 | .0035 | .0002 | .0915 | .0094 |
| 65,000 | .1150 | .0200 | .0036 | .0001 | .1114 | .0199 |
| 66,000 | .2143 | .0993 | .0040 | .0364 | .1743 | .0629 |

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | |
| Tensile strength, per square inch, under gradually increasing strains ...pounds.. | 66,000 |
| Elastic limit ...pounds.. | 21,000 |
| Extension, per inch, at elastic limit ...inch.. | 0.0010 |
| Extension, per inch, at rupture ...inch.. | 0.2143 |
| Hardness | |
| Original area of cross-section ...square inch.. | 0.333 |
| Area after rupture ...square inch.. | 0.159 |
| Position of rupture | Near middle. |
| Character of fracture | Granular and fibrous. |

*Table showing the extension, restoration, and permanent set, per inch in length, caused by the under-mentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel, 7 inches long and 0.652 inch diameter, taken from breech-block for 8-inch breech-loading chambered rifle.*

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 3,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 4,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 5,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 6,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 7,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 8,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 9,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 10,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 11,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 12,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 13,000 | .0000 | .0000 | .0000 | .8000 | .0000 | .0000 |
| 14,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 15,000 | .0001 | .0001 | .0001 | .0001 | .0000 | .0000 |
| 16,000 | .0001 | .0000 | .0001 | .0000 | .0000 | .0000 |
| 17,000 | .0001 | .0000 | .0001 | .0000 | .0000 | .0000 |
| 18,000 | .0001 | .0000 | .0001 | .0000 | .0000 | .0000 |
| 19,000 | .0001 | .0000 | .0001 | .0000 | .0000 | .0000 |
| 20,000 | .0001 | .0000 | .0001 | .0000 | .0000 | .0000 |
| 21,000 | .0001 | .0000 | .0001 | .0000 | .0000 | .0000 |
| 22,000 | .0004 | .0003 | .0004 | .0003 | .0000 | .0000 |
| 23,000 | .0004 | .0000 | .0004 | .0000 | .0000 | .0000 |
| 24,000 | .0005 | .0001 | .0005 | .0001 | .0000 | .0000 |
| 25,000 | .0005 | .0000 | .0005 | .0000 | .0000 | .0000 |
| 26,000 | .0005 | .0000 | .0005 | .0000 | .0000 | .0000 |
| 27,000 | .0005 | .0000 | .0005 | .0000 | .0000 | .0000 |
| 28,000 | .0005 | .0000 | .0005 | .0000 | .0000 | .0000 |
| 29,000 | .0007 | .0002 | .0007 | .0002 | .0000 | .0000 |
| 30,000 | .0007 | .0000 | .0007 | .0000 | .0000 | .0000 |
| 31,000 | .0008 | .0001 | .0008 | .0001 | .0000 | .0000 |
| 32,000 | .0011 | .0003 | .0011 | .0003 | .0000 | .0000 |
| 33,000 | .0011 | .0000 | .0011 | .0000 | .0000 | .0000 |
| 34,000 | .0027 | .0016 | .0013 | .0002 | .0014 | .0014 |
| 35,000 | .0044 | .0017 | .0014 | .0001 | .0030 | .0016 |
| 36,000 | .0054 | .0010 | .0014 | .0000 | .0040 | .0010 |
| 37,000 | .0064 | .0010 | .0019 | .0005 | .0045 | .0005 |
| 38,000 | .0077 | .0013 | .0017 | — .0002 | .0060 | .0015 |
| 39,000 | .0083 | .0006 | .0016 | — .0001 | .0067 | .0007 |
| 40,000 | .0090 | .0007 | .0017 | .0001 | .0073 | .0006 |
| 41,000 | .0101 | .0011 | .0018 | .0001 | .0083 | .0010 |
| 42,000 | .0113 | .0012 | .0018 | .0000 | .0095 | .0012 |
| 43,000 | .0120 | .0007 | .0020 | .0002 | .0100 | .0005 |
| 44,000 | .0127 | .0007 | .0020 | .0000 | .0107 | .0007 |
| 45,000 | .0140 | .0013 | .0023 | .0003 | .0117 | .0010 |
| 46,000 | .0149 | .0009 | .0022 | — .0001 | .0127 | .0010 |
| 47,000 | .0159 | .0010 | .0019 | — .0003 | .0140 | .0013 |
| 48,000 | .0170 | .0011 | .0022 | .0003 | .0148 | .0008 |
| 49,000 | .0183 | .0013 | .0025 | .0003 | .0158 | .0010 |
| 50,000 | .0194 | .0011 | .0023 | — .0002 | .0171 | .0013 |
| 51,000 | .0211 | .0017 | .0026 | .0003 | .0185 | .0014 |
| 52,000 | .0223 | .0012 | .0025 | — .0001 | .0198 | .0013 |
| 53,000 | .0237 | .0014 | .0026 | .0001 | .0211 | .0013 |
| 54,000 | .0254 | .0017 | .0026 | .0000 | .0228 | .0017 |
| 55,000 | .0270 | .0016 | .0025 | — .0001 | .0245 | .0017 |

*Table showing the extension, restoration, and permanent set, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 56,000 | .0287 | .0017 | .0026 | .0001 | .0261 | .0016 |
| 57,000 | .0305 | .0018 | .0025 | —.0001 | .0280 | .0019 |
| 58,000 | .0320 | .0015 | .0025 | .0000 | .0295 | .0015 |
| 59,000 | .0347 | .0027 | .0029 | .0004 | .0318 | .0023 |
| 60,000 | .0371 | .0024 | .0031 | .0002 | .0340 | .0022 |
| 61,000 | .0391 | .0020 | .0028 | —.0003 | .0363 | .0023 |
| 62,000 | .0418 | .0027 | .0030 | .0002 | .0388 | .0025 |
| 63,000 | .0444 | .0026 | .0030 | .0000 | .0414 | .0026 |
| 64,000 | .0478 | .0034 | .0031 | .0001 | .0447 | .0033 |
| 65,000 | .0493 | .0015 | .0032 | .0001 | .0461 | .0014 |
| 66,000 | .0547 | .0054 | .0036 | .0004 | .0511 | .0050 |
| 67,000 | .0587 | .0040 | .0034 | —.0002 | .0553 | .0042 |
| 68,000 | .0627 | .0040 | .0036 | .0002 | .0591 | .0038 |
| 69,000 | .1175 | .0548 | .0047 | .0011 | .1128 | .0537 |
| 70,000 | .1475 | .0300 | .0035 | —.0012 | .1440 | .0312 |

## GENERAL SUMMARY.

Specific gravity..........
Tensile strength, per square inch, under gradually increasing strains.......... pounds.. 70,000
Elastic limit..........pounds.. 34,000
Extension, per inch, at elastic limit..........inch.. 0.0027
Extension, per inch, at rupture..........inch.. 0.1475
Hardness..........
Original area of cross-section..........square inch.. 0.33378
Area after rupture..........square inch.. 0.27618
Position of rupture..........3 inches from upper shoulder.
Character of fracture..........Crystalline.

*Table showing the extension, restoration, and permanent set, per inch in length, caused by the under-mentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel,* 7.00 *inches long and* 0.652 *inch diameter, taken from breech block for* 8-*inch breech-loading chambered rifle.*

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00001 | .00001 | .00001 | .00001 | .00000 | .00000 |
| 3,000 | .00005 | .00004 | .00005 | .00004 | .00000 | .00000 |
| 4,000 | .00010 | .00005 | .00010 | .00005 | .00000 | .00000 |
| 5,000 | .00011 | .00001 | .00011 | .00001 | .00000 | .00000 |
| 6,000 | .00013 | .00002 | .00013 | .00002 | .00000 | .00000 |
| 7,000 | .00014 | .00001 | .00014 | .00001 | .00000 | .00000 |
| 8,000 | .00014 | .00000 | .00014 | .00000 | .00000 | .00000 |
| 9,000 | .00014 | .00000 | .00014 | .00000 | .00000 | .00000 |
| 10,000 | .00015 | .00001 | .00015 | .00001 | .00000 | .00000 |
| 11,000 | .00018 | .00003 | .00018 | .00003 | .00000 | .00000 |
| 12,000 | .00028 | .00010 | .00028 | .00010 | .00000 | .00000 |
| 13,000 | .00030 | .00002 | .00030 | .00002 | .00000 | .00000 |
| 14,000 | .00031 | .00001 | .00031 | .00001 | .00000 | .00000 |
| 15,000 | .00038 | .00007 | .00038 | .00007 | .00000 | .00000 |
| 16,000 | .00043 | .00005 | .00043 | .00005 | .00000 | .00000 |
| 17,000 | .00044 | .00001 | .00044 | .00001 | .00000 | .00000 |
| 18,000 | .00048 | .00004 | .00048 | .00004 | .00000 | .00000 |
| 19,000 | .00056 | .00008 | .00056 | .00008 | .00000 | .00000 |
| 20,000 | .00058 | .00002 | .00058 | .00002 | .00000 | .00000 |
| 21,000 | .00070 | .00012 | .00070 | .00012 | .00000 | .00000 |
| 22,000 | .00084 | .00014 | .00084 | .00014 | .00000 | .00000 |

*Table showing the extension, restoration, and permanent set, &c.*—**Continued.**

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 23,000 | .0024 | .00156 | .0010 | .00016 | .0014 | .0014 |
| 24,000 | .0034 | .0010 | .0010 | .0000 | .0024 | .0010 |
| 25,000 | .0045 | .0011 | .0011 | .0001 | .0034 | .0010 |
| 26,000 | .0050 | .0005 | .0005 | .0004 | .0045 | .0011 |
| 27,000 | .0065 | .0015 | .0011 | .0006 | .0054 | .0009 |
| 28,000 | .0073 | .0008 | .0013 | .0002 | .0060 | .0006 |
| 29,000 | .0083 | .0010 | .0012 | —.0001 | .0071 | .0011 |
| 30,000 | .0091 | .0008 | .0013 | .0001 | .0078 | .0007 |
| 31,000 | .0101 | .0010 | .0011 | —.0002 | .0090 | .0012 |
| 32,000 | .0111 | .0010 | .0014 | .0003 | .0097 | .0007 |
| 33,000 | .0121 | .0010 | .0014 | .0000 | .0107 | .0010 |
| 34,000 | .0131 | .0010 | .0016 | .0002 | .0115 | .0008 |
| 35,000 | .0140 | .0009 | .0016 | .0000 | .0124 | .0009 |
| 36,000 | .0149 | .0009 | .0014 | —.0002 | .0135 | .0011 |
| 37,000 | .0160 | .0011 | .0015 | .0001 | .0145 | .0010 |
| 38,000 | .0174 | .0014 | .0016 | .0002 | .0158 | .0013 |
| 39,000 | .0190 | .0016 | .0019 | .0003 | .0171 | .0013 |
| 40,000 | .0203 | .0013 | .0019 | .0000 | .0184 | .0013 |
| 41,000 | .0215 | .0012 | .0024 | .0005 | .0191 | .0007 |
| 42,000 | .0228 | .0013 | .0017 | —.0007 | .0211 | .0020 |
| 43,000 | .0243 | .0015 | .0019 | .0002 | .0224 | .0013 |
| 44,000 | .0260 | .0017 | .0022 | .0003 | .0238 | .0014 |
| 45,000 | .0274 | .0014 | .0021 | —.0001 | .0253 | .0015 |
| 46,000 | .0291 | .0017 | .0021 | .0000 | .0270 | .0017 |
| 47,000 | .0304 | .0013 | .0021 | .0000 | .0283 | .0013 |
| 48,000 | .0321 | .0017 | .0020 | —.0001 | .0301 | .0018 |
| 49,000 | .0344 | .0023 | .0024 | .0004 | .0320 | .0019 |
| 50,000 | .0364 | .0020 | .0024 | .0000 | .0340 | .0020 |
| 51,000 | .0390 | .0026 | .0022 | —.0002 | .0368 | .0028 |
| 52,000 | .0417 | .0027 | .0020 | —.0002 | .0397 | .0029 |
| 53,000 | .0443 | .0026 | .0626 | .0006 | .0417 | .0020 |
| 54,000 | .0471 | .0028 | .0026 | .0000 | .0445 | .0028 |
| 55,000 | .0504 | .0033 | .0040 | .0014 | .0464 | .0019 |
| 56,000 | .0538 | .0034 | .0028 | —.0012 | .0570 | .0046 |
| 57,000 | .0578 | .0040 | .0027 | —.0001 | .0550 | .0041 |
| 58,000 | .0624 | .0046 | .0030 | .0003 | .0594 | .0043 |
| 59,000 | .0670 | .0046 | .0029 | —.0001 | .0641 | .0047 |
| 60,000 | .0737 | .0067 | .0036 | .0007 | .0701 | .0060 |
| 61,000 | .0788 | .0051 | .0031 | —.0005 | .0757 | .0056 |
| 62,000 | .0871 | .0083 | .0034 | .0003 | .0837 | .0080 |
| 63,000 | .0958 | .0087 | .0033 | —.0001 | .0925 | .0088 |
| 64,000 | .1095 | .0137 | .0035 | .0002 | .1060 | .0135 |
| 65,000 | .1231 | .0136 | .0036 | .0001 | .1195 | .0135 |
| 66,000 | .1467 | .0236 | .0022 | —.0014 | .1445 | .0250 |
| 67,000 | .2031 | .0564 | .0028 | .0006 | .2003 | .0558 |

## GENERAL SUMMARY.

Specific gravity .......... 7.8650
Tensile strength, per square inch .......... pounds.. 82,440
Elastic limit .......... pounds.. 23,000
Extension, per inch, at elastic limit .......... inch.. 0.0024
Extension, per inch, at rupture .......... inch.. 0.2031
Hardness ..........
Original area of cross-section .......... square inch.. 0.3338
Area after rupture .......... square inch.. 0.23758
Position of rupture .......... ½ length from upper shoulder.
Character of fracture .......... Fibrous and crystalline.

*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel (oil tempered), 3.00 inches long and 0.653 inch diameter, taken radially from jacket for 8-inch breech-loading chambered rifle.*

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 0000 | 0. 0000 | 0. 0000 | 0. 0000 | 0. 0000 | 0. 0000 |
| 2, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 3, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 4, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 5, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 6, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 7, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 8, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 9, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 10, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 11, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 12, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 13, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 14, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 15, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 16, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 17, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 18, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 19, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 20, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 21, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 22, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 23, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 24, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 25, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 26, 000 | . 0060 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 27, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 28, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 29, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 30, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 31, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 32, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 33, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 34, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 35, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 36, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 37, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 38, 000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 | . 0000 |
| 39, 000 | . 0003 | . 0003 | . 0003 | . 0003 | . 0000 | . 0000 |
| 40, 000 | . 0003 | . 0000 | . 0003 | . 0000 | . 0000 | . 0000 |
| 41, 000 | . 0003 | . 0000 | . 0003 | . 0000 | . 0000 | . 0000 |
| 42, 000 | . 0003 | . 0000 | . 0003 | . 0000 | . 0000 | . 0000 |
| 43, 000 | . 0006 | . 0003 | . 0006 | . 0003 | . 0000 | . 0000 |
| 44, 000 | . 0013 | . 0007 | . 00013 | . 0007 | . 0000 | . 0000 |
| 45, 000 | . 0026 | . 0013 | . 0020 | . 0007 | . 0006 | . 0006 |
| 46, 000 | . 0040 | . 0014 | . 0014 | — . 00016 | . 0016 | . 0010 |
| 47, 000 | . 0053 | . 0013 | . 0020 | . 0006 | . 0033 | . 0017 |
| 48, 000 | . 0060 | . 0007 | . 0024 | . 0004 | . 0036 | . 0003 |
| 49, 000 | . 0066 | . 0006 | — . 0023 | . 0001 | . 0043 | . 0007 |
| 50, 000 | . 0076 | . 0010 | . 0026 | . 0003 | . 0050 | . 0007 |
| 51, 000 | . 0083 | . 0007 | . 0023 | — . 0003 | . 0060 | . 0010 |
| 52, 000 | . 0093 | . 0010 | . 0027 | . 0004 | . 0066 | . 0006 |
| 53, 000 | . 0103 | . 0010 | . 0027 | . 0000 | . 0076 | . 0010 |
| 54, 000 | . 0110 | . 0007 | . 0027 | . 0000 | . 0083 | . 0007 |
| 55, 000 | . 0116 | . 0006 | . 0026 | — . 0001 | . 0090 | . 0007 |
| 56, 000 | . 0120 | . 0004 | . 0027 | . 0001 | . 0093 | . 0003 |
| 57, 000 | . 0126 | . 0006 | . 0026 | — . 0001 | . 0100 | . 0007 |
| 58, 000 | . 0133 | . 0007 | . 0027 | . 0001 | . 0106 | . 0006 |
| 59, 000 | . 0143 | . 0010 | . 0030 | . 0003 | . 0113 | . 0007 |
| 60, 000 | . 0153 | . 0010 | . 0030 | . 0000 | . 0123 | . 0010 |
| 61, 000 | . 0166 | . 0013 | . 0033 | . 0003 | . 0133 | . 0010 |
| 62, 000 | . 0173 | . 0007 | . 0033 | . 0000 | . 0140 | . 0007 |
| 63, 000 | . 0183 | . 0010 | . 0030 | — . 0003 | . 0153 | . 0013 |
| 64, 000 | . 0193 | . 0010 | . 0030 | . 0000 | . 0163 | . 0010 |
| 65, 000 | . 0200 | . 0007 | . 0030 | . 0000 | . 0170 | . 0007 |
| 66, 000 | . 0213 | . 0013 | . 0033 | . 0003 | . 0180 | . 0010 |
| 67, 000 | . 0226 | . 0613 | . 0033 | . 0000 | . 0193 | . 0013 |
| 68, 000 | . 0240 | . 0014 | . 0040 | . 0007 | . 0200 | . 0007 |
| 69, 000 | . 0253 | . 0013 | . 0037 | . 0003 | . 0216 | . 0016 |

*Table showing the extension, restoration, and permanent set, &c.*—**Continued.**

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 70,000 | .0266 | .0013 | .0040 | .0003 | .0226 | .0010 |
| 71,000 | .0280 | .0014 | .0040 | .0000 | .0240 | .0014 |
| 72,000 | .0293 | .0013 | .0040 | .0000 | .0253 | .0013 |
| 73,000 | .0313 | .0020 | .0040 | .0000 | .0273 | .0020 |
| 74,000 | .0333 | .0020 | .0043 | .0003 | .0290 | .0017 |
| 75,000 | .0353 | .0020 | .0047 | .0004 | .0306 | .0016 |
| 76,000 | .0366 | .0013 | .0040 | —.0007 | .0326 | .0020 |
| 77,000 | .0383 | .0017 | .0043 | .0003 | .0340 | .0014 |
| 78,000 | .0406 | .0023 | .0046 | .0003 | .0360 | .0020 |
| 79,000 | .0426 | .0020 | .0046 | .0000 | .0380 | .0020 |
| 80,000 | .0453 | .0027 | .0050 | .0001 | .0406 | .0026 |
| 81,000 | .0486 | .0033 | .0050 | .0003 | .0436 | .0030 |
| 82,000 | .0506 | .0020 | .0046 | —.0004 | .0460 | .0024 |
| 83,000 | .0533 | .0027 | .0043 | .0003 | .0490 | .0030 |
| 84,000 | .0573 | .0040 | .0053 | .0010 | .0520 | .0030 |
| 85,000 | .0620 | .0047 | .0054 | .0001 | .0566 | .0046 |
| 86,000 | .0656 | .0036 | .0050 | —.0004 | .0606 | .0040 |
| 87,000 | .0716 | .0060 | .0050 | .0000 | .0666 | .0060 |
| 88,000 | .0770 | .0054 | .0054 | .0004 | .0716 | .0050 |
| 89,000 | .0840 | .0070 | .0054 | .0000 | .0786 | .0070 |
| 90,000 | .0946 | .0106 | .0056 | .0002 | .0890 | .0104 |
| 91,000 | .1123 | .0177 | .0063 | .0007 | .1060 | .0170 |
| 92,000 | .1600 | .0477 | .0040 | —.0023 | .1560 | .0500 |

GENERAL SUMMARY.

| | | |
|---|---|---|
| Specific gravity | | ...... |
| Tensile strength, per square inch, under gradually increasing strains | pounds.. | 92,[illegible] |
| Elastic limit | pounds.. | 45,[illegible] |
| Extension, per inch, at elastic limit | inch.. | 0.0[illegible] |
| Extension, per inch, at rupture | inch.. | 0.1[illegible] |
| Hardness | | ... |
| Original area of cross-section | square inch.. | 0.3[illegible] |
| Area after rupture | square inch.. | 0.2[illegible] |
| Position of rupture | | Near middle |
| Character of fracture | | Granular and fibrous |

*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel,* 3.00 *inches long and* 0.651 *inch diameter, taken from jacket for 8-inch breech-loading chambered rifle.*

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 9,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 10,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 11,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 12,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 13,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 15,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 16,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 17,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 18,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |

*Table showing the extension, restoration, and permanent set, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 19,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 20,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 21,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 22,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 23,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 24,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 25,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 26,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 27,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 28,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 29,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 30,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 31,000 | .00003 | .00003 | .00003 | .00003 | .00000 | .00000 |
| 32,000 | .00003 | .00000 | .00003 | .00000 | .00000 | .00000 |
| 33,000 | .00006 | .00003 | .00006 | .00003 | .00000 | .00000 |
| 34,000 | .00006 | .00000 | .00006 | .00000 | .00000 | .00000 |
| 35,000 | .00013 | .00007 | .00013 | .00007 | .00000 | .00000 |
| 36,000 | .00013 | .00000 | .00013 | .00000 | .00000 | .00000 |
| 37,000 | .00013 | .00000 | .00013 | .00000 | .00000 | .00000 |
| 38,000 | .00020 | .00007 | .00020 | .00007 | .00000 | .00000 |
| 39,000 | .00020 | .00000 | .00020 | .00000 | .00000 | .00000 |
| 40,000 | .00020 | .00000 | .00020 | .00000 | .00000 | .00000 |
| 41,000 | .00026 | .00006 | .00026 | .00006 | .00000 | .00000 |
| 42,000 | .00026 | .00000 | .00026 | .00000 | .00000 | .00000 |
| 43,000 | .00026 | .00000 | .00026 | .00000 | .00000 | .00000 |
| 44,000 | .00036 | .00010 | .00036 | .00010 | .00000 | .00000 |
| 45,000 | .00026 | .00224 | .00020 | .00164 | .00006 | .00006 |
| 46,000 | .0040 | .0014 | .0020 | .0000 | .0020 | .0014 |
| 47,000 | .0053 | .0013 | .0023 | .0003 | .0030 | .0010 |
| 48,000 | .0063 | .0010 | .0026 | .0003 | .0037 | .0007 |
| 49,000 | .0070 | .0007 | .0023 | — .0003 | .0047 | .0010 |
| 50,000 | .0076 | .0006 | .0026 | .0003 | .0050 | .0003 |
| 51,000 | .0080 | .0004 | .0026 | .0000 | .0054 | .0004 |
| 52,000 | .0090 | .0010 | .0026 | .0000 | .0064 | .0010 |
| 53,000 | .0093 | .0003 | .0026 | .0000 | .0067 | .0003 |
| 54,000 | .0100 | .0007 | .0026 | .0000 | .0074 | .0007 |
| 55,000 | .0106 | .0006 | .0026 | .0000 | .0080 | .0006 |
| 56,000 | .0116 | .0010 | .0030 | .0004 | .0086 | .0006 |
| 57,000 | .0123 | .0007 | .0026 | — .0004 | .0097 | .0011 |
| 58,000 | .0130 | .0007 | .0026 | .0000 | .0104 | .0007 |
| 59,000 | .0140 | .0010 | .0030 | .0004 | .0110 | .0006 |
| 60,000 | .0150 | .0010 | .0030 | .0000 | .0120 | .0010 |
| 61,000 | .0163 | .0013 | .0036 | .0006 | .0127 | .0007 |
| 62,000 | .0173 | .0010 | .0036 | .0000 | .0137 | .0010 |
| 63,000 | .0186 | .0013 | .0033 | — .0003 | .0153 | .0016 |
| 64,000 | .0196 | .0010 | .0033 | .0000 | .0163 | .0010 |
| 65,000 | .0203 | .0007 | .0033 | .0000 | .0170 | .0007 |
| 66,000 | .0213 | .0010 | .0036 | .0003 | .0177 | .0007 |
| 67,000 | .0223 | .0010 | .0036 | .0000 | .0187 | .0010 |
| 68,000 | .0236 | .0013 | .0036 | .0000 | .0200 | .0013 |
| 69,000 | .0253 | .0017 | .0040 | .0004 | .0213 | .0013 |
| 70,000 | .0270 | .0017 | .0036 | — .0004 | .0234 | .0021 |
| 71,000 | .0283 | .0013 | .0036 | .0000 | .0247 | .0013 |
| 72,000 | .0300 | .0017 | .0036 | .0000 | .0264 | .0017 |
| 73,000 | .0320 | .0020 | .0043 | .0007 | .0277 | .0013 |
| 74,000 | .0343 | .0023 | .0043 | .0000 | .0300 | .0023 |
| 75,000 | .0356 | .0013 | .0040 | — .0003 | .0316 | .0016 |
| 76,000 | .0383 | .0027 | .0043 | .0003 | .0340 | .0024 |
| 77,000 | .0403 | .0020 | .0046 | .0003 | .0357 | .0017 |
| 78,000 | .0423 | .0020 | .0043 | — .0003 | .0380 | .0023 |
| 79,000 | .0446 | .0023 | .0043 | .0000 | .0403 | .0023 |
| 80,000 | .0470 | .0024 | .0046 | .0003 | .0424 | .0021 |
| 81,000 | .0503 | .0033 | .0046 | .0003 | .0457 | .0033 |
| 82,000 | .0533 | .0030 | .0046 | .0000 | .0487 | .0030 |
| 83,000 | .0563 | .0030 | .0046 | .0000 | .0517 | .0030 |
| 84,000 | .0606 | .0043 | .0033 | .0000 | .0573 | .0056 |
| 85,000 | .0646 | .0040 | .0050 | — .0013 | .0596 | .0023 |
| 86,000 | .0696 | .0050 | .0053 | .0017 | .0643 | .0047 |
| 87,000 | .0753 | .0057 | .0050 | .0003 | .0703 | .0060 |
| 88,000 | .0816 | .0063 | .0050 | — .0000 | .0766 | .0063 |
| 89,000 | .0903 | .0087 | .0053 | .0003 | .0850 | .0084 |
| 90,000 | .1036 | .0133 | .0053 | .0000 | .0983 | .0133 |
| 91,000 | .1113 | .0077 | .0030 | .0023 | .1083 | .0100 |

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7.8620 |
| Tensile strength, per square inch ........ pounds.. | 104,480 |
| Elastic limit ........ pounds.. | 45,000 |
| Extension, per inch, at elastic limit ........ inch.. | 0.0026 |
| Extension, per inch, at rupture ........ inch.. | 0.1113 |
| Hardness | |
| Original area of cross-section ........ square inch. | 0.33285 |
| Area after rupture ........ square inch.. | 0.28938 |
| Position of rupture | Near middle. |
| Character of fracture | Fibrous and granular. |

*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel, oil-tempered, 3.00 inches long and 0.653 inch diameter, taken from the interior front jacket for 8-inch breech-loading chambered rifle.*

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 3,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 4,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 5,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 6,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 7,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 8,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 9,000 | .0000 | .0000 | .0000 | 0000 | .0000 | .0000 |
| 10,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 11,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 12,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 13,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 14,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 15,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 16,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 17,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 18,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 19,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 20,000 | .0003 | .0003 | .0003 | .0003 | .0000 | .0000 |
| 21,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 22,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 23,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 24,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 25,000 | .0006 | .0003 | .0006 | .0003 | .0000 | .0000 |
| 26,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 27,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 28,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 29,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 30,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 31,000 | .0010 | .0004 | .0010 | .0004 | .0000 | .0000 |
| 32,000 | .0010 | .0000 | .0010 | .0000 | .0000 | .0000 |
| 33,000 | .0010 | .0000 | .0010 | .0000 | .0000 | .0000 |
| 34,000 | .0010 | .0000 | .0010 | .0000 | .0000 | .0000 |
| 35,000 | 0010 | .0000 | .0010 | .0000 | .0000 | .0000 |
| 36,000 | 0013 | .0003 | .0013 | .0003 | .0000 | .0000 |
| 37,000 | 0013 | .0000 | 0013 | .0000 | .0000 | .0000 |
| 38,000 | 0013 | .0000 | .0013 | .0000 | .0000 | .0000 |
| 39,000 | .0013 | .0000 | .0013 | .0000 | .0000 | .0000 |
| 40,000 | 0013 | .0000 | .0013 | .0000 | .0000 | .0000 |
| 41,000 | .0013 | .0000 | .0013 | .0000 | .0000 | .0000 |
| 42,000 | .0013 | .0000 | .0013 | .0000 | .0000 | .0000 |
| 43,000 | .0013 | .0000 | .0013 | .0000 | .0000 | .0000 |
| 44,000 | .0016 | .0003 | .0016 | .0003 | .0000 | .0000 |
| 45,000 | .0016 | .0000 | .0016 | .0000 | .0000 | .0000 |
| 46,000 | .0016 | .0000 | .0016 | .0000 | .0000 | .0000 |
| 47,000 | .0016 | .0000 | .0016 | .0000 | .0000 | .0000 |
| 48,000 | .0016 | .0000 | .0016 | .0000 | .0000 | .0000 |
| 49,000 | .0016 | .0000 | .0016 | .0000 | .0000 | .0000 |
| 50,000 | .0016 | .0000 | .0016 | .0000 | .0000 | .0000 |
| 51,000 | .0016 | .0000 | .0016 | .0000 | .0000 | .0000 |
| 52,000 | .0020 | .0004 | .0020 | .0004 | .0000 | .0000 |
| 53,000 | .0020 | .0000 | .0020 | .0000 | .0000 | .0000 |
| 54,000 | .0020 | .0000 | .0020 | .0000 | .0000 | .0000 |
| 55,000 | .0020 | .0000 | .0020 | .0000 | .0000 | .0000 |
| 56,000 | .0020 | .0000 | .0020 | .0000 | .0000 | .0000 |

*Table showing the extension, restoration, and permanent set, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 57, 000 | .0020 | .0000 | .0020 | .0000 | .0000 | .0000 |
| 58, 000 | .0020 | .0000 | .0020 | .0000 | .0000 | .0000 |
| 59, 000 | .0020 | .0000 | .0020 | .0000 | .0000 | .0000 |
| 60, 000 | .0023 | .0003 | .0023 | .0003 | .0000 | .0000 |
| 61, 000 | .0030 | .0007 | .0017 | — .0006 | .0013 | .0013 |
| 62, 000 | .0073 | .0043 | .0023 | .0006 | .0050 | .0037 |
| 63, 000 | .0096 | .0026 | .0023 | .0000 | .0073 | .0023 |
| 64, 000 | .0103 | .0007 | .0027 | .0004 | .0076 | .0003 |
| 65, 000 | .0106 | .0003 | .0026 | — .0001 | .0080 | .0004 |
| 66, 000 | .0110 | .0004 | .0024 | — .0002 | .0086 | .0006 |
| 67, 000 | .0116 | .0006 | .0026 | .0002 | .0090 | .0004 |
| 68, 000 | .0126 | .0010 | .0030 | .0004 | .0096 | .0006 |
| 69, 000 | .0136 | .0010 | .0030 | .0000 | .0106 | .0010 |
| 70, 000 | .0143 | .0007 | .0033 | .0003 | .0110 | .0004 |
| 71, 000 | .0146 | .0003 | .0030 | — .0003 | .0116 | .0006 |
| 72, 000 | .0153 | .0007 | .0033 | .0003 | .0120 | .0004 |
| 73, 000 | .0160 | .0007 | .0030 | — .0003 | .0130 | .0010 |
| 74, 000 | .0170 | .0010 | .0034 | .0004 | .0136 | .0006 |
| 75, 000 | .0180 | .0010 | .0030 | — .0004 | .0150 | .0014 |
| 76, 000 | .0186 | .0006 | .0030 | .0000 | .0156 | .0006 |
| 77, 000 | .0200 | .0014 | .0034 | .0004 | .0166 | .0010 |
| 78, 000 | .0210 | .0010 | .0034 | .0000 | .0176 | .0010 |
| 79, 000 | .0220 | .0010 | .0034 | .0000 | .0186 | .0010 |
| 80, 000 | .0236 | .0016 | .0036 | .0002 | .0200 | .0014 |
| 81, 000 | .0243 | .0007 | .0040 | .0004 | .0203 | .0003 |
| 82, 000 | .0253 | .0010 | .0040 | .0000 | .0213 | .0010 |
| 83, 000 | .0263 | .0010 | .0037 | — .0003 | .0226 | .0013 |
| 84, 000 | .0280 | .0017 | .0040 | .0003 | .0240 | .0014 |
| 85, 000 | .0290 | .0010 | .0037 | — .0003 | .0253 | .0013 |
| 86, 000 | .0310 | .0020 | .0040 | .0003 | .0270 | .0017 |
| 87, 000 | .0323 | .0013 | .0040 | .0000 | .0283 | .0013 |
| 88, 000 | .0340 | .0017 | .0040 | .0000 | .0300 | .0017 |
| 89, 000 | .0360 | .0020 | .0040 | .0000 | .0320 | .0020 |
| 90, 000 | .0380 | .0020 | .0040 | .0000 | .0340 | .0020 |
| 91, 000 | .0403 | .0023 | .0043 | .0003 | .0360 | .0020 |
| 92, 000 | .0423 | .0020 | .0047 | .0004 | .0376 | .0016 |
| 93, 000 | .0446 | .0023 | .0046 | — .0001 | .0400 | .0024 |
| 94, 000 | .0473 | .0027 | .0047 | .0001 | .0426 | .0026 |
| 95, 000 | .0500 | .0027 | .0050 | .0003 | .0450 | .0024 |
| 96, 000 | .0526 | .0026 | .0050 | .0000 | .0476 | .0026 |
| 97, 000 | .0570 | .0044 | .0050 | .0000 | .0520 | .0044 |
| 98, 000 | .0600 | .0036 | .0040 | — .0004 | .0560 | .0040 |
| 99, 000 | .0663 | .0057 | .0050 | .0004 | .0613 | .0043 |
| 100, 000 | .0701 | .9038 | .0035 | — .0015 | .0666 | .0053 |
| 101, 000 | .0790 | .0089 | .0054 | .0019 | .0736 | .0070 |
| 102, 000 | .0833 | .0043 | .0023 | — .0031 | .0810 | .0074 |

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | |
| Tensile strength, per square inch, under gradually increasing strains .......... pounds.. | 102, 000 |
| Elastic limit .......... pounds.. | 61, 000 |
| Extension, per inch, at elastic limit .......... inch.... | 0. 0030 |
| Extension, per inch, at rupture .......... inch.... | 0. 0833 |
| Hardness | |
| Original area of cross-section .......... square inch.... | 0. 33490 |
| Area after rupture .......... square inch.... | 0. 29706 |
| Position of rupture .......... | Near lower shoulder. |
| Character of fracture .......... | Granular and slightly fibrous. |

*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel (oil tempered), 3.00 inches long and 0.653 inch diameter, taken from the interior from jacket for 8-inch breech-loading chambered rifle.*

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 3,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 4,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 5,000 | .0000 | .0009 | .0000 | .0000 | .0000 | .0000 |
| 6,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 7,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 8,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 9,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 10,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 11,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 12,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 13,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 14,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 15,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 16,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 17,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 18,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 19,000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 20,000 | .0003 | .0003 | .0003 | .0003 | .0000 | .0060 |
| 21,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 22,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 23,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 24,000 | .0003 | .0000 | .0003 | .0000 | .0000 | .0000 |
| 25,000 | .0006 | .0003 | .0006 | .0003 | .0000 | .0000 |
| 26,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 27,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 28,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 29,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 30,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 31,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 32,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 33,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 34,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 35,000 | .0006 | .0000 | .0006 | .0000 | .0000 | .0000 |
| 36,000 | .0010 | .0004 | .0010 | .0004 | .0000 | .0000 |
| 37,000 | .0010 | .0000 | .0010 | .0000 | .0000 | .0000 |
| 38,000 | .0010 | .0000 | .0010 | .0000 | .0000 | .0000 |
| 39,000 | .0013 | .0003 | .0013 | .0003 | .0000 | .0000 |
| 40,000 | .0013 | .0000 | .0018 | .0000 | .0000 | .0000 |
| 41,000 | .0016 | .0003 | .0016 | .0003 | .0000 | .0000 |
| 42,000 | .0026 | .0010 | .0016 | .0000 | .0010 | .0010 |
| 43,000 | .0053 | .0027 | .0013 | — .0003 | .0040 | .0030 |
| 44,000 | .0073 | .0020 | .0020 | .0007 | .0053 | .0013 |
| 45,000 | .0083 | .0010 | .0017 | — .0003 | .0060 | .0013 |
| 46,000 | .0090 | .0007 | .0017 | .0000 | .0073 | .0007 |
| 47,000 | .0100 | .0010 | .0020 | .0003 | .0080 | .0007 |
| 48,000 | .0110 | .0010 | .0024 | .0004 | .0086 | .0006 |
| 49,000 | .0116 | .0006 | .0020 | — .0004 | .0096 | .0010 |
| 50,000 | .0126 | .0010 | .0023 | .0003 | .0103 | .0007 |
| 51,000 | .0133 | .0007 | .0020 | — .0003 | .0113 | .0010 |
| 52,000 | .0140 | .0007 | .0020 | .0000 | .0120 | .0007 |
| 53,000 | .0150 | .0010 | .0024 | .0004 | .0126 | .0006 |
| 54,000 | .0160 | .0010 | .0027 | .0003 | .0133 | .0007 |
| 55,000 | .0170 | .0010 | .0024 | — .0003 | .0146 | .0013 |
| 56,000 | .0183 | .0013 | .0023 | — .0001 | .0160 | .0014 |
| 57,000 | .0196 | .0013 | .0023 | .0000 | .0173 | .0013 |
| 58,000 | .0216 | .0020 | .0026 | .0003 | .0190 | .0017 |
| 59,000 | .0226 | .0010 | .0026 | .0000 | .0200 | .0010 |
| 60,000 | .0243 | .0017 | .0027 | .0001 | .0216 | .0016 |
| 61,000 | .0263 | .0020 | .0027 | .0000 | .0236 | .0020 |
| 62,000 | .0270 | .0007 | .0024 | — .0003 | .0240 | .0010 |
| 63,000 | .0296 | .0026 | .0030 | .0006 | .0266 | .0020 |
| 64,000 | .0323 | .0027 | .0030 | .0000 | .0293 | .0027 |
| 65,000 | .0356 | .0033 | .0030 | .0000 | .0326 | .0033 |
| 66,000 | .0370 | .0014 | .0030 | .0000 | .0340 | .0014 |
| 67,000 | .0390 | .0020 | .0027 | — .0003 | .0363 | .0023 |
| 68,000 | .0426 | .0036 | .0033 | .0006 | .0393 | .0030 |
| 69,000 | .0450 | .0024 | .0030 | — .0003 | .0420 | .0027 |

*Table showing the extension, restoration, and permanent set, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 70,000 | .0493 | .0043 | .0043 | .0013 | .0450 | .0030 |
| 71,000 | .0520 | .0027 | .0034 | —.0009 | .0486 | .0036 |
| 72,000 | .0546 | .0026 | .0036 | .0002 | .0510 | .0024 |
| 73,000 | .0586 | .0040 | .0040 | .0004 | .0546 | .0036 |
| 74,000 | .0620 | .0036 | .0037 | —.0003 | .0583 | .0037 |
| 75,000 | .0673 | .0053 | .0037 | .0000 | .0636 | .0053 |
| 76,000 | .0743 | .0070 | .0040 | .0003 | .0703 | .0067 |
| 77,000 | .0806 | .0063 | .0040 | .0000 | .0766 | .0063 |
| 78,000 | .0903 | .0097 | .0043 | .0003 | .0860 | .0094 |
| 79,000 | .1000 | .0097 | .0037 | —.0006 | .0963 | .0103 |
| 80,000 | .1186 | .0186 | .0053 | .0016 | .1133 | .0170 |
| 81,000 | .1516 | .0330 | .0066 | .0013 | .1450 | .0317 |
| 82,000 | .2583 | .1067 | .0083 | .0017 | .2500 | .1050 |

GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | |
| Tensile strength, per square inch, under gradually increasing strains ... pounds.. | 82,000 |
| Elastic limit ... pounds.. | 42,000 |
| Extension, per inch, at elastic limit ... inch.. | 0.0026 |
| Extension, per inch, at rupture ... inch.. | 0.2583 |
| Hardness | |
| Original area of cross-section ... square inch.. | 0.33490 |
| Area after rupture ... square inch.. | 0.16723 |
| Position of rupture | 1 inch from upper shoulder. |
| Character of fracture | Fibrous (silky). |

*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of Firth's steel,* 10.00 *inches long and* 0.0652 *inch diameter, taken from breech block for* 8-*inch breech-loading chambered rifle.*

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00001 | .00001 | .00001 | .00001 | .00000 | .00000 |
| 3,000 | .00002 | .00001 | .00002 | .00001 | .00000 | .00000 |
| 4,000 | .00004 | .00002 | .00004 | .00002 | .00000 | .00000 |
| 5,000 | .00008 | .00004 | .00008 | .00004 | .00000 | .00000 |
| 6,000 | .00010 | .00002 | .00010 | .00002 | .00000 | .00000 |
| 7,000 | .00015 | .00005 | .00015 | .00005 | .00000 | .00000 |
| 8,000 | .00020 | .00005 | .00020 | .00005 | .00000 | .00000 |
| 9,000 | .00023 | .00003 | .00023 | .00003 | .00000 | .00000 |
| 10,000 | .00029 | .00006 | .00029 | .00006 | .00000 | .00000 |
| 11,000 | .00031 | .00002 | .00031 | .00002 | .00000 | .00000 |
| 12,000 | .00033 | .00002 | .00033 | .00002 | .00000 | .00000 |
| 13,000 | .00038 | .00005 | .00038 | .00005 | .00000 | .00000 |
| 14,000 | .00041 | .00003 | .00041 | .00003 | .00000 | .00000 |
| 15,000 | .00047 | .00006 | .00047 | .00006 | .00000 | .00000 |
| 16,000 | .00052 | .00005 | .00052 | .00005 | .00000 | .00000 |
| 17,000 | .00057 | .00005 | .00057 | .00005 | .00000 | .00000 |
| 18,000 | .00061 | .00004 | .00061 | .00004 | .00000 | .00000 |
| 19,000 | .00070 | .00009 | .00070 | .00009 | .00000 | .00000 |
| 20,000 | .00110 | .00040 | .00050 | --.00020 | .00060 | .00060 |
| 21,000 | .0035 | .0024 | .0007 | -.00020 | .0028 | .0022 |
| 22,000 | .0045 | .0010 | .0010 | .0003 | .0035 | .0007 |
| 23,000 | .0051 | .0006 | .0009 | --.0001 | .0042 | .0007 |
| 24,000 | .0059 | .0008 | .0009 | .0000 | .0050 | .0008 |

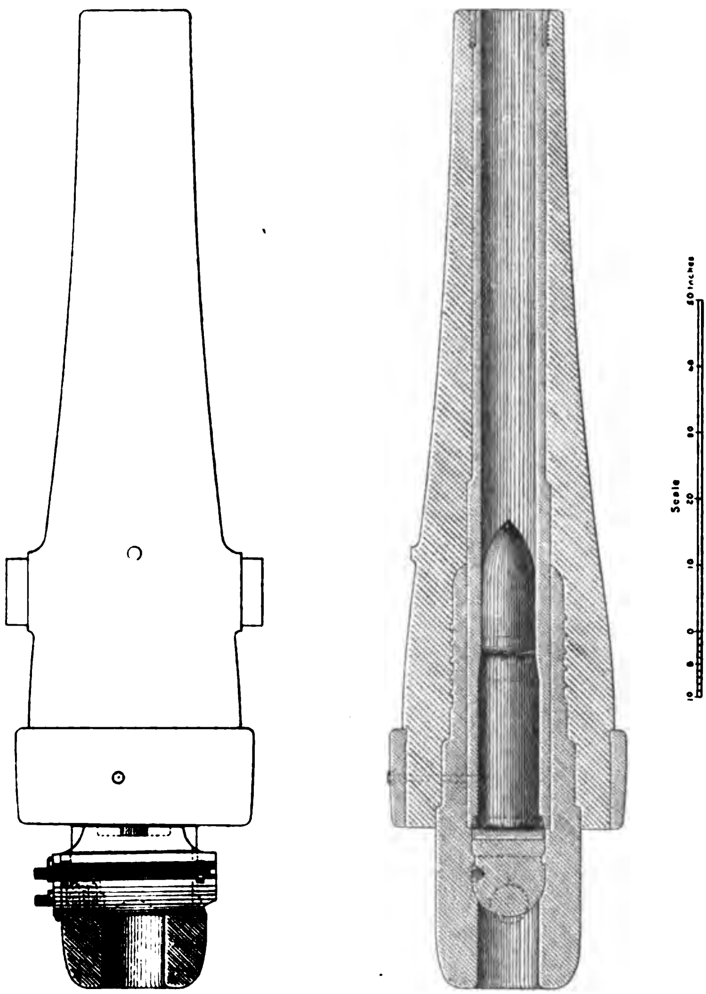
*Table showing the extension, restoration, and permanent set, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 25, 000 | .0071 | .0012 | .0011 | .0002 | .0060 | .0010 |
| 26, 000 | .0080 | .0009 | .0010 | — .0001 | .0070 | .0010 |
| 27, 000 | .0087 | .0007 | .0009 | — .0001 | .0078 | .0008 |
| 28, 000 | .0098 | .0011 | .0013 | .0004 | .0085 | .0007 |
| 29, 000 | .0105 | .0007 | .0009 | — .0004 | .0096 | .0011 |
| 30, 000 | .0126 | .0021 | .0012 | .0003 | .0114 | .0018 |
| 31, 000 | .0134 | .0008 | .0017 | .0005 | .0117 | .0003 |
| 32, 000 | .0144 | .0010 | .0015 | — .0002 | .0129 | .0012 |
| 33, 000 | .0157 | .0013 | .0012 | — .0003 | .0145 | .0016 |
| 34, 000 | .0167 | .0010 | .0015 | .0003 | .0152 | .0008 |
| 35, 000 | .0183 | .0016 | .0014 | — .0001 | .0169 | .0017 |
| 36, 000 | .0199 | .0016 | .0014 | .0000 | .0185 | .0016 |
| 37, 000 | .0210 | .0011 | .0016 | .0002 | .0194 | .0009 |
| 38, 000 | .0219 | .0009 | .0011 | — .0005 | .0208 | .0014 |
| 39, 000 | .0247 | .0028 | .0017 | .0006 | .0230 | .0022 |
| 40, 000 | .0260 | .0013 | .0018 | .0001 | .0242 | .0012 |
| 41, 000 | .0275 | .0015 | .0016 | — .0002 | .0259 | .0017 |
| 42, 000 | .0293 | .0018 | .0018 | .0002 | .0275 | .0016 |
| 43, 000 | .0315 | .0022 | .0018 | .0000 | .0297 | .0022 |
| 44, 000 | .0340 | .0025 | .0020 | .0002 | .0320 | .0023 |
| 45, 000 | .0361 | .0021 | .0020 | .0000 | .0341 | .0021 |
| 46, 000 | .0380 | .0019 | .0020 | .0000 | .0360 | .0010 |
| 47, 000 | .0418 | .0038 | .0021 | .0001 | .0397 | .0037 |
| 48, 000 | .0435 | .0017 | .0020 | — .0001 | .0415 | .0018 |
| 49, 000 | .0467 | .0032 | .0021 | .0001 | .0446 | .0031 |
| 50, 000 | .0491 | .0024 | .0011 | — .0010 | .0480 | .0034 |
| 51, 000 | .0530 | .0039 | .0024 | .0013 | .0506 | .0026 |
| 52, 000 | .0575 | .0045 | .0022 | — .0002 | .0553 | .0047 |
| 53, 000 | .0610 | .0035 | .0021 | — .0001 | .0591 | .0038 |
| 54, 000 | .0671 | .0061 | .0026 | .0005 | .0645 | .0054 |
| 55, 000 | .0725 | .0054 | .0025 | — .0001 | .0700 | .0055 |
| 56, 000 | .0800 | .0075 | .0025 | .0000 | .0775 | .0075 |
| 57, 000 | .0850 | .0050 | .0033 | .0008 | .0817 | .0042 |
| 58, 000 | .0935 | .0085 | .0028 | — .0005 | .0907 | .0090 |
| 59, 000 | .1075 | .0140 | .0025 | — .0003 | .1050 | .0143 |
| 60, 000 | .1250 | .0175 | .0033 | .0008 | .1217 | .0167 |
| 61, 000 | .1465 | .0215 | .0038 | .0005 | .1427 | .0210 |
| 62, 000 | .2175 | .0710 | .0022 | — .0016 | .2153 | .0726 |

## GENERAL SUMMARY.

Specific gravity ........................................................................
Tensile strength, per square inch, under gradually increasing strains................pounds.. 62,[illegible]
Elastic limit ........................................................................pounds.. 20,[illegible]
Extension, per inch, at elastic limit ........................................................inch.. 0.[illegible]
Extension, per inch, at rupture ........................................................inch.. 0.2175
Hardness ........................................................................
Original area of cross-section ........................................................square inch.. 0.333
Area after rupture ........................................................................square inch.. 0.2697
Position of rupture ........................................One-third of its length from upper shoulder
Character of fracture........................................Light gray metallic luster crystalline.

8 INCH B. L. CHAMBERED RIFLE.




Appendix 37b—1881.

# APPENDIX 37c.

## CONSTRUCTION REPORT OF THREE 3.20-INCH BREECH-LOADING CHAMBERED RIFLES.

(One plate.)

### DESCRIPTION.

These guns were converted from 3-inch wrought-iron muzzle-loading rifles on the plan pursued in the case of the 3.18-inch breech-loading rifle described in the report of the Chief of Ordnance for 1880; that is, by cutting off the breech near the bottom of the bore, and screwing in from the rear a steel breech-receiver, which forms the rear end of the bore, and contains and supports the sliding breech-block.

Besides the increase of 0.02 inch in diameter of bore and a slight change in the position of the vent, the most important distinction between the two constructions consists in changes in certain details of the rifling, the twist of the latter being changed from 7 to 8 feet, and the width of grooves in the same increased.

#### RIFLING, CHAMBERING, AND VENTING.

| | | |
|---|---|---|
| Number of grooves | | 22 |
| Number of lands | | 22 |
| Width of lands | inch.. | 0.125 |
| Width of grooves | do... | 0.332 |
| Depth of grooves | do... | 0.05 |
| Twist uniform, one turn in | feet.. | 8 |

The chamber is 8.25 inches in length and 3.78 inches in diameter. The rear of the chamber is enlarged to form the seat for the gas-check. The vent is in a vertical plane passing through the axis and at a distance of 3.63 inches from the bottom of the bore.

### FABRICATION.

The guns selected were 3-inch wrought-iron muzzle-loading rifles Nos. 902, 939, and 895, and the work was performed at the West Point foundry.

The breech-receivers and blocks were made of Midvale steel, the former tempered in oil.

Specimens from the receivers, when tested, gave the following results:

| Specimen. | Number of gun. | Tenacity. | Reduction in area. | Extension per inch at rupture. | Where tested. | Remarks. |
|---|---|---|---|---|---|---|
| | | *Lbs.* | *Pr. ct.* | *Inch.* | | |
| 1 | 2 | 55,423 | 65.95 | 0.345 | Midvale Steel Works | Longitudinal after annealing.* |
| 2 | 2 | 58,182 | 55.91 | 0.355 | ......do | Transverse after annealing.* |
| 3 | 3 | 85,053 | 58.66 | 0.250 | West Point Foundry | Longitudinal after annealing. |
| 4 | 4 | 71,891 | 58.54 | 0.240 | ......do | Do. |

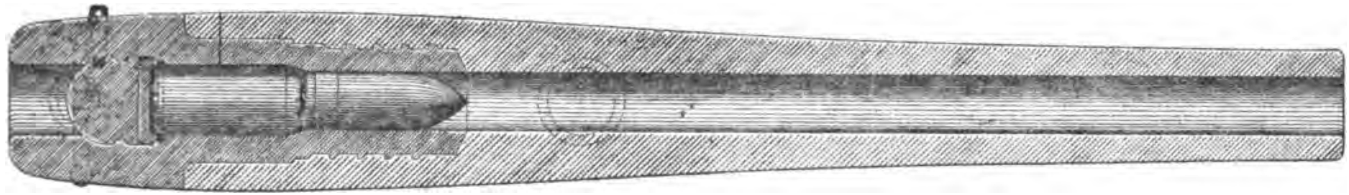
* These specimens were tested from ring previously detached from ingot and then annealed with it.

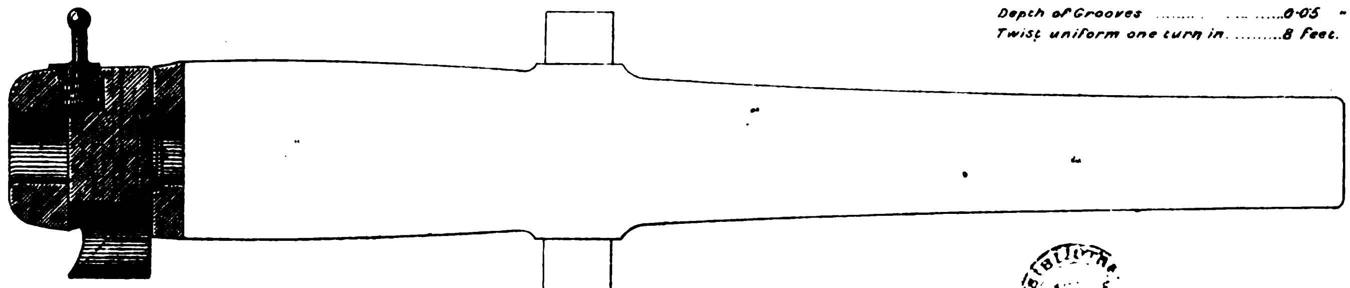
PRINCIPAL DIMENSIONS.

| | | |
|---|---|---|
| Total length of converted rifle | inches.. | 72.65 |
| Length of bore | do.... | 64.65 |
| Length of rifled portion of bore | do.... | 56.60 |
| Diameter of bore across lands | do.... | 3.20 |
| Length of cylindrical part of chamber | do.... | 7.25 |
| Length of bevel of chamber | do.... | 1.00 |
| Total length of chamber | do.... | 8.25 |
| Diameter of chamber | do.... | 3.78 |
| Length of breech-receiver in rear of casing | do.... | 9.50 |
| Total length of breech-receiver | do.... | 25.00 |
| Diameter of breech-receiver over threads | do.... | 6.20 |
| Length of screw in breech-receiver | do.... | 7.50 |
| Pitch of thread of screw on breech-receiver | do.... | 1.50 |
| Length of breech-block | do.... | 11.13 |
| Width of breech-block | do.... | 4.75 |
| Number of lands | | 22 |
| Number of grooves | | 22 |
| Width of grooves | inches.. | 0.332 |
| Width of lands | do.... | 1.125 |
| Depth of grooves | do.... | 0.05 |
| Pitch of rifling (uniform), one turn in | feet.. | 8 |
| Axis of vent from bottom of bore | inches.. | 3.63 |

| | | No. 2. | No. 3. | No. 4. |
|---|---|---|---|---|
| Weight of breech-block | pounds.. | 124 | 120 | 125 |
| Weight of gun complete | do.... | 826 | 825 | 826 |
| Preponderance | do.... | 43 | 43 | 43 |

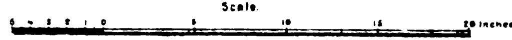
# 320 INCH B. L. CHAMBERED RIFLE.





**RIFLING.**

| | |
|---|---|
| Nº of Grooves | 22· |
| Nº of Lands | 22· |
| Width of Lands | 0·125 in. |
| Width of Grooves | 0·332 " |
| Depth of Grooves | 0·05 " |
| Twist uniform one turn in | 8 Feet. |




Appendix 87a—1881.

PLATE I.

## APPENDIX 37d.

### CONSTRUCTION OF FIELD-CARRIAGE FOR 3.20-INCH BREECH-LOADING RIFLE, WITH DESCRIPTION OF THE ENGELHARDT CARRIAGE.

(Three plates.)

WEST POINT FOUNDRY,
*Cold Springs, N. Y., January* 31, 1881.

COLONEL: I have the honor to transmit inspection and construction reports of field carriage for 3.20-inch breech-loading rifle, constructed at this foundry in compliance with your orders of August 2, 1880. I also inclose a translation from the Revüe d'Artillerie, August, 1877, of the preliminary discussion to an article on the Engelhardt carriage; the detailed description of which I have already translated and forwarded to your office.

To the inclosed translation I have added sufficient numerical data to permit a comparison of the carriage just constructed with those cited by Colonel Engelhardt, and on the plan he has selected.

The flanging of the cheeks of the carriage, which was undertaken by the founders without hesitation, proves to have been a matter of more difficulty than they anticipated. Not only did the operation prove exceedingly laborious, but cannot be considered entirely successful.

I am now preparing drawings and descriptions of the plant, which I think is needed to insure rapid and accurate work in flanging the cheeks of future constructions, together with an estimate of its cost. I submit, however, with this report a design of the West Point foundry, by which both flanging and the use of angle iron are practically dispensed with.

The principal difficulty in the construction of both carriages made at the foundry has been found in shaping the trunnion and axle-beds; and the advantage claimed by the design submitted is, that by using bronze, and casting in a single piece the reinforcing cheeks, the front and rear transoms, and the two plates which form the trunnion and axle-beds, this difficulty will be removed.

I am, colonel, very respectfully, your obedient servant,

C. W. WHIPPLE,
*Lieutenant of Ordnance, Inspector.*

Col. S. CRISPIN, U. S. A.,
*Constructor of Ordnance.*

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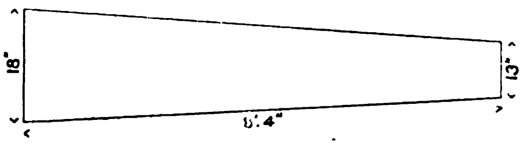
### CONSTRUCTION REPORT OF FIELD-CARRIAGE FOR 3.20-INCH BREECH LOADING RIFLE.

This carriage differs from the one made at this foundry under an order from the Constructor of Ordnance dated December 18, 1879, in three particulars, namely: The axle and lunette plate are made of low steel instead of wrought iron; angle iron is not used for stiffening the cheeks,

which are flanged in order to accomplish the same object; and certain dimensions are increased to secure greater strength.

The cheeks are made of steel plates $\frac{5}{16}$ inch thick. They were obtained from the Nashua Steel Works, in the following shape:




Three cast-iron forms were then made, one for shaping the axle bed, one for the trunnion bed, and the third for shaping the upper curved outline of the cheeks. The flanging was accomplished by heating short portions of the edge of the plate, in lengths, say, of about 12 inches, which were then hammered over the forms, first with a heavy wooden mallet, and then, after reheating, with sledges, in order to sharpen the edges. The steel stood this very trying treatment fairly well. It drew out very thin, however, at the bed for the axle and trunnions, and in one place, along the under rectilinear edge, where the strain was presumably least, fractured completely across the flange, necessitating a small patch, which was riveted to the flange.

It being desired that the pressure on the trail should not exceed 175 pounds, after the cheeks had been flanged, except that portion of each in the vicinity of the axle bed, they were temporarily assembled and the gun mounted. This gun was the unaltered 3-inch muzzle-loading rifle sent here for conversion into a 3.20-inch breech-loading rifle. Consequently, to represent the increase of weight and preponderance of the converted gun and the weight of the different parts of the carriage not then attached, a weight was suspended from the carriage at the seat for the elevating screw. The carriage was then suspended, the trail resting on the platform of the scales, and the axle moved until the weight indicated was 175 pounds. This required the axis of the axle to be placed 1.1 inches in rear of the axis of the trunnions, and instructions were then given to complete the flanging with this object in view.

Through an error in the boiler shop, this flanging was so performed that the axis of the axle would fall considerably below the lower edge of the cheeks, and in correcting this the distance between the two axes was reduced to 0.86 inch. As a consequence, after the completion of the carriage, the pressure was found to be about 20 pounds in excess of what was prescribed.

The same alterations reduced the distance between the axes of the trunnions and axle from 12.7 to 12.035 inches.

The different parts are as follows:

The axle, made of Midvale steel, and the trail or lunette plate of steel, cast to shape by the Chester Steel Castings Company, both being of the best, though low, steel.

The cheeks, which form the body of the carriage, reinforced toward the head of the carriage by wrought-iron plates $\frac{5}{16}$ inch thick, fastened to the inside of the cheeks by six rivets countersunk on the outside. These cheeks are assembled by means of a wrought-iron transom $\frac{3}{8}$ inch thick attached by three rivets to either cheek, normal to the lower edge; by a small front curved transom of $\frac{5}{16}$-inch iron fastened by two rivets to the flange of each cheek directly in front of the axle; by two 1-inch assembling bolts in rear of the elevating screw box, and by the lunette

plate, which is attached to the flange of each cheek plate by two upper and three lower rivets ⅝ inch diameter, with their outer heads countersunk.

The trunnion bed plates, which, unlike those of the preceding carriage, are distinct from the axle plates, are 2 inches wide. Each is fastened to the flange beneath at the trunnion bed by three rivets with countersunk heads.

The axle bed plates: These are 3 inches wide, and extend beyond the cheeks 0.9 inch on the exterior and 0.1 inch on the interior. Each is fastened to the under flange by two rivets within the axle bed, and by the bolts which secure the axle strap. These straps are of the same width as the plates, and both are tapered from their outer faces to the cheeks.

Two axle braces, embracing the axle just in rear of the shoulder of the axle arm and attached by pins to brass seats fastened to the cheeks of the trail by four bolts. The braces are made of wrought iron, 2″ by 1″ cross-section. The arms of the seats are 0.5 inch thick, the pins 1.1 inch diameter.

The wheels, of oak, with steel tire and brass nave.

| | | |
|---|---|---|
| Number of spokes | | 12 |
| Diameter of flange of nave | inches.. | 10.5 |
| Length of inner box | do.. | 10 |
| Diameter of inner box | do.. | 4.3 |
| Diameter of outer box | do.. | 5.5 |

The spokes are fastened to the nave by ⅝-inch bolts, with round head and the nut on the inside.

The brake, which is a wooden bar 2.5 inches square, carrying at each end an iron shoe, swinging on an iron shank, which is pinned to the bar. The bar is connected by a system of rods and braces to the axle by means of a shaft working in a seat bolted on the under side and to the middle of the axle, the lower end of the shaft having a screw on it with a ⅛-inch pitch, which works in a socket at the upper end of the rods and braces. By means of a handle on the outer end of the shaft the brake can be moved to or from the axle, and the shoes tightened to or released from the wheel tires.

The elevating apparatus, consisting of a double screw hinged by braces to the forward part of the cheeks, and working in a brass box pivoted to the inside of the cheeks.

The trail chest, with lid formed of iron plate, ⅛ inch thick.

The trail handspike, with its attachment to the lunette-plate, which was made stronger in all its parts than in the preceding carriage, and the catch of tempered steel to secure it over the lid of the trail chest when not in use.

The cap-squares and keys, linchpins and washers, rammer-head stop. In the first carriage made this stop was made of a piece of angle iron, and fractured along the edge almost at the first fire, although the rammer was not in place, and consequently it supported no strain but that due to the shock and vibrations. The stop is now made of an iron plate in which the fiber runs in the direction of the trail instead of across it.

PRINCIPAL DIMENSIONS AND WEIGHTS.

| | | |
|---|---|---|
| Distance between the inside of the trunnion plates | inches.. | 9.6 |
| Diameter of trunnion holes | do.... | 3.7 |
| Distance from axis of trunnions to axis of axle | do.... | 12.7 |
| Horizontal distance between axis of trunnions and axis of axle gun unlimbered | inches.. | 1.1 |
| Height of axis of trunnions above the ground | do.... | 41.2 |

| | | |
|---|---|---|
| Distance between the points of contact of the trail and wheels with the ground line | inches.. | 72.0 |
| Distance from front of wheels to end of trail, the piece unlimbered | do.... | 114.0 |
| Thickness of steel cheek plates | do.... | 0.3125 |
| Length of axle | do.... | 43.5 |
| Diameter of axle | do.... | 3.5 |
| Width of braces | do.... | 2.0 |
| Thickness of braces | do.... | 1.0 |
| Wheels: | | |
| Height of | do.... | 57.0 |
| Track of | do.... | 60.0 |
| Dish of | do.... | 1.375 |
| Diameter of brass nave | do.... | 10.5 |
| Number of spokes | | 12 |
| Number of fellies | | 7 |
| Weights: | | |
| Carriage without wheels or implements | pounds.. | 715 |
| One wheel | do.... | 180 |
| Carriage complete without implements | do.... | 1,075 |

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## NEW IRON FIELD CARRIAGE FOR LONG-RANGE GUNS.

To-day every European power regards as a necessity the adoption of long-range guns, fired with heavy charges. The construction of the guns does not involve any great difficulties; the entire question consists in the choice of the material employed, and has been solved in different ways in different countries.

In England field guns are made of iron, the bore being reinforced by a steel tube. Prussia makes hers of steel; Sweden, of cast iron. In France, Switzerland, Italy, Austria, and Russia, field guns are made of bronze, and in the last four cases cast in iron molds; besides, of late, in Austria and Russia the resistance of the bore is increased by the compression of the walls.

The guns themselves have not, in their different countries, met with serious complaint, but it is not entirely the same with the carriages used by most of the nations of Europe; everywhere it is found that their recoil is excessive, in spite of their already very considerable weight.

The design and construction of field carriages for long-range guns involves very great difficulties, because they must satisfy at the same time two essentially contradictory conditions.

In the first place, the carriage ought to be capable of offering resistance to the recoil; in the second place, it ought to be light and give a moderate recoil; but the action of the gun upon its carriage is transferred by a shock, and it has been proved that the resistance of a body to a shock is proportional to its section; so that to satisfy the first condition it is necessary to make the carriage heavy, in opposition to the requirements of the second condition; the effect of fire upon the carriage, moreover, being the more destructive the heavier the carriage. Heavy guns are less severe on carriages than light ones, provided they fire projectiles of the same weight, under the same conditions; besides, in consequence of the adoption of long-range guns, they have been led, in order to insure the safety of the carriage, to give to guns more weight than the tenacity of the metal employed in their construction requires. Moreover, to secure for the carriage sufficient resisting power, they have given to their different parts excessive dimensions; the total weight has, in consequence, been so increased that, for long-range guns, the gun and its carriage together show a very considerable weight, of which fact one will be convinced by consulting the following table:

| | Metal used in carriage. | Weight. | | | | Initial velocity. |
|---|---|---|---|---|---|---|
| | | Projectile. | Gun. | Carriage. | Gun and carriage. | |
| | | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Feet.* |
| England | Iron | 15.4 | 1,300.7 | 1,344.8* | 2,645.5 | 1,409.1 |
| France | ...do | 23.8 | 1,543.0 | 1,440.0 | 2,983.0 | 1,453.0 |
| Do | ...do | 15.4 | 1,344.8 | 1,543.0 | 2,887.8 | 1,279.2 |
| Do | ...do | 11.0 | 1,014.1 | 1,146.4 | 2,160.5 | 1,369.4 |
| Prussia* | Steel | 15.4 | 992.1 | 1,190.5 | 2,182.6 | 1,458.0 |
| Austria | Iron and steel | 13.9 | 1,080.25 | 1,190.5 | 2,270.75 | 1,476.0 |
| Sweden | Iron | 8.6 | 826.7 | 1,047.2 | 1,873.9 | 1,279.2 |
| Switzerland | ...do | 12.1 | 959.0 | 1,036.2 | 1,995.2 | 1,197.2 |
| Italy | ...do | 8.8 | 672.4 | 904.0 | 1,576.4 | 1,318.6 |
| Russia | ...do | 24.25 | 1,371.26 | 1,080.25 | 2,451.50 | 1,198.8 |
| Do | ...do | 12.6 | 723.11 | 1,080.25 | 1,803.26 | 1,399.0 |

* The old Prussian 6-pounder carriage weighs 11,020 pounds.

It appears from this table that, except in Russia, the weights of carriages designed to be subjected to firing with heavy charges, with initial velocities greater than 1,246 feet, and projectiles weighing more than 8.8 pounds, vary between 1,146 and 1,543 pounds, while the weights of the gun and carriage combined vary between 2,160 and 2,982 pounds. These weights are considerable, in view of the extreme mobility required of field artillery in actual service.

So far, no generally admitted process has been devised for measuring with accuracy the destructive effects produced by the gun, under fire, upon its carriage; but mechanics teaches us that in the shock a part of the living force of the body producing it is expended in displacing the molecules of both bodies.

The action of the gun upon its carriage being transmitted, as before stated, by a shock, one part of the living force of the gun must be found absorbed by the displacement of the molecules of the trunnions and of the carriage, and if we can measure this loss of living force we will have an approximate idea of the action of the gun upon its carriage.

Suppose then—

$m$ = the mass of the projectile.
B = the mass of the charge.
$v$ = the initial velocity of the projectile.
$m'$ = the mass of the gun.
$m''$ = the mass of the carriage.
$v'$ = the velocity of recoil of the gun at the first instant.
$v''$ = the actual velocity of recoil of the gun and carriage.

We have, between the quantities of motion, the relation

$$\left(m+\frac{B}{2}\right)v=m'v'$$

which gives

$$v'=\frac{\left(m+\frac{B}{2}\right)v}{m'}$$

The living force $\frac{m'v'^2}{2}$ of the gun can then be expressed

$$\frac{m'}{2}\left(\frac{m+\frac{B}{2}}{m'}\right)^2v^2=\frac{1}{2}\frac{\left(m+\frac{B}{2}\right)^2v^2}{m'}$$

The quantity of motion of the gun and carriage is represented by

$$(m'+m'')\,v'' = m'v' = \left(m+\frac{B}{2}\right)v$$

from which

$$v'' = \frac{\left(m+\frac{B}{2}\right)v}{m'+m''}$$

Also, for the living force of the gun and carriage,

$$\frac{(m'+m'')\,v''^{-2}}{2} = \frac{1}{2}\,(m'+m'')\,\frac{\left(m+\frac{B}{2}\right)^2 v^2}{(m'+m'')^2} = \frac{\frac{1}{2}\left(m+\frac{B}{2}\right)^2 v^2}{m'+m''}$$

The difference between the living force of the gun at the moment of the shock and that of the gun and carriage together immediately after, expresses the quantity of living force absorbed in the displacement of the molecules of the trunnions and the carriage. This difference is:

$$\frac{\frac{1}{2}\left(m+\frac{B}{2}\right)^2 v^2}{m'} - \frac{\frac{1}{2}\left(m+\frac{B}{2}\right)^2 v^{-2}}{m'+m''} = \frac{1}{2}\left(m+\frac{B}{2}\right)^2 v^{-2}\left(\frac{1}{m}-\frac{1}{m'+m''}\right)$$

$$= \frac{1}{2}\left(m+\frac{B}{2}\right)^2 v^{-2}\,\frac{m''}{m'(m'+m'')} = A$$

and placing $\frac{m'}{m''}=h$, it becomes

$$A = \frac{\frac{1}{2}\left(m+\frac{B}{2}\right)^2 v^2}{(h+1)m'}$$

This last formula shows us that for the same initial velocity the difference A varies inversely as "$h$," that is to say, that the greater the ratio of the weight of the gun to the weight of the carriage the less the carriage suffers.

We might, as an application, form a table showing the values of A for most of the service field carriages, by means of the numerical data before given, and we would find then that the Prussian field carriage for the 3.54-inch gun is the one most strained. In this case the relation of the mass of the gun to that of the carriage is entirely to the disadvantage of the latter, and nevertheless it stands fire satisfactorily, though relatively much lighter than the other carriages. Its strength is due to the substitution of steel for iron, the *elastic limit* of the first being much higher than that of the second. But steel, in spite of valuable qualities, is somewhat unreliable, and its application for gun carriage constructions has not yet been sufficiently investigated to enable us to certify to its suitability.

It is a fact, however, that in Prussia the trail has been broken many times; and in Austria one of four carriages furnished by Krupp has had its cheek plate broken.

It must be observed that the Prussian 3.54-inch gun upon its carriage

weighs 2,183 pounds, or 441 pounds more than the ordinary Russian 9 pounder on its carriage.

It is seen, therefore, that the study of the mode of construction of existing carriages furnishes us no facts sufficient to establish a system at once light and suitable for guns of long range, irrespective of the weights of the parts; so that to resolve this problem we are forced to the study of an entirely new system of construction, the essential principles of which we must ascertain. A detailed description must therefore be given.

In designing a carriage, it is necessary above all things to make a comparative study of the different parts of existing carriages; and to facilitate this work the principal dimensions of Russian and foreign carriages are united in Table C, at the end of this article. This table shows that all recent carriages are sensibly shorter than our own.

Since it is possible to construct a new carriage shorter than existing carriages, this fact can be utilized in seeking to diminish the weight.

We then find we can further reduce weight by replacing the angle iron, by a flange formed on the cheek plate itself, an arrangement which, besides, secures stiffness in the cheeks more thoroughly than the angle iron.

The cheeks cannot be made of any but a good quality of metal, for none other will stand the operation of flanging; and the construction is spared the accidental flying off of bolts, which may be at any time expected where angle iron is used.

The greatest difficulty is found in procuring the flanged cheeks. In Prussia all the carriages are constructed in the national foundries, while the cheeks are furnished by Krupp's works, which keep a secret the process by which they flange the steel plates. In Austria they have been obliged to give up the use of flanged cheeks in consequence of the difficulty of making them.

In Russia the solution of this question also presented great difficulties, but thanks to the co-operation of the Solonbieff Foundry, we have succeeded in preparing the die and in determining the character of iron which will stand the treatment.

To-day the question of flanging iron cheeks may be considered as definitely settled in Russia.

Equal attention must be paid to the subject of securely assembling the cheeks.

In Russian carriages already constructed, this assembling is accomplished by means of bolts.

This mode of assembling has the advantage of allowing the carriage to be quickly dismounted, but presents also, for this very reason, a great inconvenience; on the march the nuts are loosened from the shocks to the carriage to such an extent that the two cheeks are no longer firmly united, an impossible mishap were transoms used instead.

Now, in the new carriage not only are the cheeks assembled by bolts, but also by transoms, the latter being attached obliquely with reference to the edges of the cheeks instead of being normal to them, as in carriages of other powers. This arrangement is even more effective in uniting the cheeks, the obliquity of the transoms offering opposition to all lateral bending of the carriage.

In order to avoid excessive weight in the new carriage, the cheeks are made to converge to such extent as to allow the ordinary trail transom to be replaced by a narrow trail plate, which embraces the cheeks above and below, and unites them in the most thorough way.

This arrangement serves to distribute strains between the two cheeks,

and prevents the possibility of one cheek being exposed to a shock of any kind unaided.

These improvements increase the stiffness of the carriage, but do not by any means modify, so to speak, the effects of the gun upon it.

These effects can be expressed, as previously shown, by the formula,

$$\frac{\frac{1}{2}\left(m+\frac{B}{2}\right)^{-2} v^{-2}}{(h+1)\,m'}$$

and depend upon the value of $h$; that is to say, upon the relation between the weight or mass of the gun and the weight or mass of the carriage.

Consequently to effect a sensible diminution in the destructive effects of the gun upon its carriage, it will be necessary to sensibly reduce the weight of the latter; but as the carriage is also for purposes of transportation, requiring therefore the use of wheels and seats, the weights of which cannot be reduced, it is impossible to materially lighten the carriage.

The destructive effect of the gun can, however, be reduced, by dividing the carriage into two parts; one the carriage body, and the other the axle with the wheels and seats.

This division is obtained as follows:

The axle, instead of being permanently bound to the cheeks, is allowed to slide backward and forward in stirrups; at the end of the axle arm it is held by two braces united together at the other end by a square cross-bar. This cross-bar, as well as the axle, is allowed to slide either way in slots cut for it in the cheeks.

The cross-bar, braces, and axle consequently constitute a *chassis*, upon which are arranged the seats, and which, supported by wheels, form the "truck" of the carriage. This "truck" is united to the cheeks by means of two bolts attached by looped heads to the square traverse bar. These bolts pass through both the middle transom ($c$ $c$) and the iron plate in rear of it, between which are placed a number of sheets of cork. In the latest carriages the cork is replaced by rubber, which is the more durable. On the ends of the bolts are nuts, by the tightening of which the cork is compressed, and the traverse bar, and consequently the axle, drawn toward the transom. The axle recoils until it reaches the rear bearing of its stirrups.

The plates of cork form an elastic cushion, the depth of which is reduced by tightening the nuts on the bolts, from 7 inches to 3.5 inches. It is then under a pressure of about 10,800 pounds, as can be seen by an examination of the following table of the thickness of a cushion, with a cross-section of 43.75 square inches.

| Pressure. | Thickness. | Compression. |
|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* |
| | 7.00 | |
| 2,921 | 4.33 | 2.67 |
| 8,631 | 3.78 | 3.22 |
| 11,375 | 3.35 | 3.65 |
| 14,440 | 3.15 | 3.85 |
| 18,275 | 2.66 | 4.34 |
| 22,387 | 2.44 | 4.56 |
| 30,335 | 2.09 | 4.91 |
| 37,279 | 1.94 | 5.06 |
| 45,106 | 1.88 | 5.12 |
| 52,838 | 1.81 | 5.19 |
| 66,810 | 1.75 | 5.25 |
| 162,511 | 1.61 | 5.38 |

The weight of the first of the two parts into which the carriage may be said to be divided is reduced to 430 pounds. This part first receives the shock of the gun at the discharge; then, when its inertia is overcome, the motion is transmitted to the second part through the intervention of the cushion, which, under the fire of the 9-pounder gun with an initial velocity of 1,200 feet, is at once compressed 1.5 inches.

Table B at the end of the article, in which are given the living force absorbed by the old and modern carriage, shows that with the ordinary 9-pounder, the living force absorbed is only 1,757 foot-pounds for the upper part of the carriage, while it was 3,789 foot-pounds in carriages of the old construction.

In firing the long range 9-pounder gun with an initial velocity of 1,200 feet, the new carriage only absorbs 3,579 foot-pounds, as shown in the table, an examination of which shows that generally the new carriage suffers less under fire than that of the old pattern.

To determine, then, the amount of work performed in the compression of the cushion, let us bear in mind that before the discharge it supports an initial pressure of 10,800 pounds, as before stated; at the discharge it is still more compressed to the extent of 1.5 inches; that is to say, its thickness is reduced from 3.5 inches to 2.0 inches, and the preceding table shows that this height corresponds approximately to a pressure of 30,864 pounds, which represents the maximum strain transmitted by the bolts at the discharge.

The work performed by the resistance to this compression is then

$$\frac{10803 + 30864}{2} \times 0.0125 \text{ feet} = 2604.0 \text{ foot-pounds.}$$

Table B shows that the carriage without the buffer absorbs 6,015 foot-pounds, while the carriage with the buffer absorbs only 3,579 foot-pounds, or a difference of 2,436 foot-pounds, which is practically equal to the work performed by the buffer. Did this latter not exist, the braces and cheeks must absorb just this amount of work; but, thanks to its compression, it is decidedly diminished; without this compression the different parts would be subjected to strains much too considerable, so much the more as the cheeks resist by compression and the braces by extension.

To show this, let us endeavor to determine approximately the resistance of the cheeks to compression and of the braces to extension in the case where the axle is permanently attached to the cheeks.

The length of the braces is 30 inches, which is equal to the distance from their point of attachment to the cheeks to the trunnion beds. The area of the cross-section of the cheeks is 6 square inches and that of braces 3.84 square inches.

The work performed by the resistance of the cheeks and the braces in maintaining an equilibrium with the shock will be expressed by the following:

$$(6\,\mathrm{R}x + 3.84\,\mathrm{R}'x') \times 30$$

in which R represents the maximum strain of compression per square inch of cross-section which wrought iron can stand, and $x$ the corresponding reduction per inch in length; R′ the tensile strength per square inch of wrought iron, and $x'$ the corresponding extension per inch in length: R and R′ being expressed in pounds and $x$ and $x'$ in inches. If we assume as the elastic limit for iron under a strain of extension $\mathrm{R}' =$

21270, and under a strain of compression R = 14223, then we have according to Hodgkinson $x = 0.002$ and $x' = 0.00075$.

Applying these values to the above expression we obtain as a result 579 foot-pounds. This is the maximum resistance of which the cheeks and braces are capable without submitting to permanent disfigurement, and this is less than a third of that offered by the buffer. It is evident therefore that whenever the axle is attached to the cheeks in a fixed position the carriage will be always disabled, and that it is consequently absolutely indispensable to increase the dimensions of the cheeks and braces, in spite of the consequent increase in the weight of the carriage.

In order to avoid this inconvenience we are obliged to resort to the use of steel, the elastic limit of which is much higher than that of iron, equally with respect to compression as to extension, but it then becomes necessary to exercise the utmost care in the construction, and to only employ steel of the very best quality.

The correctness of these deductions has been fully supported by facts.

The first carriage for a long-range gun was made without a buffer, after the type of the Swiss carriage, and furnished with a cylindrical axle 3.25 inches in diameter, firmly attached by three straps, under the cheeks and between them. At the end of 30 rounds fired from the 9-pounder gun, the axle was bent and was replaced by a heavier axle, with a square body measuring 4 inches on a side. This new axle was as seriously bent after 10 rounds fired from the 9-pounder with a charge of 5.4 pounds. They then tried to mount the carriage on the ordinary service axle stiffened by braces; but the axle broke at the end of 250 rounds, the fracture showing the poor quality of the metal. When the broken axle was examined it was found that the holes for the bolts used in assembling it to the carriage were worn oblong, and the bolts themselves twisted and sheared.

In consequence of this mishap, a buffer was attached to the carriage, which, thus modified, stood without the least disfigurement 604 rounds fired from the ordinary 9-pounder and heavy 4-pounder gun, 80 of which were fired with the trail embedded in the earth so as to entirely suppress recoil; at the end of the firing the trail was found buried almost to the elevating screw.

Following this model, a new carriage was constructed which endured at once without disfigurement 1,190 rounds, fired from the long-range 4-pounder gun. After this trial, they replaced the axle by another, stronger one, in order to make it fit for service with the 9-pounder gun. The carriage so modified, then received a long-range 9-pounder gun with its chamber enlarged so as to secure an initial velocity of 1,200 feet. They then fired 404 rounds with this gun, using charges of 5.64 pounds of large grain powder, 100 rounds being fired under an angle of elevation of 20°. This trial the carriage stood successfully. It was then provided with seats mounted upon cork springs, which at once proved themselves serviceable. Before this arrangement the seats at the end of 200 rounds showed that they were damaged, and at the close of the proof of the carriage were found almost entirely detached; seats mounted on the cork springs are not, however, exposed to such a mishap.

With the third carriage 1,600 rounds were fired from the 4-pounder long-range gun. The carriage and seats stood this proof without injury. The excess of strength thus proved permits the application to the carriage of another improvement in the shape of a spade fastened to the foot of the trail designed to diminish the recoil. In consequence of this improvement the gun, after 20 rounds, is found to have retired, in consequence of the recoil, not more than 7 paces from the position first occu-

pied. This diminution in the amount of recoil facilitates the rapidity of fire.

The trial sustained by the carriage with the 9-pounder gun, having an initial velocity of 1,200 feet, shows that it is possible to increase this velocity, even with the 4-pounder cavalry gun.

It is shown in Table B that the velocity of recoil is 18.20 feet for the long-range 9-pound gun, with an initial velocity of 1,200 feet, while it is only 17.5 feet for the 4-pounder cavalry gun with an initial velocity of 1,400 feet; besides, the 9-pounder gun weighs 1,371 pounds, while the 4-pounder weighs but 723 pounds. The action of the 9-pounder is, therefore, much greater upon the buffer than that of the 4-pounder, and it can be seen from Table B that the former is much more severe upon its carriage.

Practice, therefore, confirms these deductions. In firing the 9-pounder long range gun, the buffer is compressed 1.5 inches, while it only reaches 0.75 inch under the fire of the 4-pounder cavalry gun. Thanks to the favorable results thus obtained, it is possible to change from the ordinary field gun to the long-range gun without increasing the total weight of the gun and carriage, as is shown by the following figures:

| Caliber. | Weight. | | |
|---|---|---|---|
| | Gun. | Carriage. | Piece. |
| 9-POUNDER. | Pounds. | Pounds. | Pounds. |
| Service | 1,336 | 1,173 | 2,509 |
| Long-range | 1,371 | 1,080 | 2,450 |
| 4-POUNDER. | | | |
| Service | 723 | 1,014 | 1,737 |
| Long-range | 723 | 1,080 | 1,803 |

It is seen, therefore, that the division of the carriage into two distinct parts, and the introduction of the buffer, form a system of construction totally different from that of any other nation; a system for which are claimed over others the following advantages:

It enables, without increase of weight, the construction of carriages for long-range guns out of wrought iron, a metal in which every confidence can be placed;

It abolishes the necessity of increasing the weight of the gun in spite of the adoption of long-range guns;

It enables the recoil to be reduced to almost nothing, or when necessary absolutely suppressed;

Finally, it permits the use of a single carriage for all field guns, old or new.

TABLE A.—*Field carriages for modern rifled guns.*

| | Designation of gun. | Caliber, in inches. | Weight, in pounds. | | | | Initial velocity, in feet. | | | Living force, in foot-pounds. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Charge. | Projectile. | Gun. | Carriage. | Projectile. | Gun. | Gun carriage. | Gun. | Gun and carriage. | Difference. |
| England: | | | | | | | | | | | | |
| Woolwich | 16-pounder | 3.58 | 2.98 | 15.98 | 1,300 | 1,345 | 1,309 | 12.61 | 6.33 | 6,869 | 3,485 | 3,384 |
| | 9-pounder | 3.00 | 1.76 | 8.85 | 904 | 1,312 | 1,376 | 15.00 | 9.38 | 3,188 | 1,338 | 1,850 |
| Whitworth* | 9-pounder | 2.7 ×2.4 | 2.25 | 9.03 | 1,003 | 1,190 | 1,466 | 13.28 | 6.21 | 2,773 | 1,305 | 1,468 |
| | 6-pounder | 2.28×2.09 | 1.57 | 6.33 | 893 | 1,190 | 1,466 | 14.30 | 4.99 | 2,033 | 723 | 1,310 |
| Austria | 3.15 inch | 2.96 | 2.07 | 9.92 | 657 | 1,120 | 1,376 | 23.91 | 8.77 | 5,892 | 2,188 | 3,709 |
| | 3.54 inch | 3.42 | 3.31 | 13.81 | 1,080 | 1,190 | 1,476 | 23.42 | 11.09 | 6,269 | 4,374 | 4,895 |
| France | 5-pounder | 2.96 | 1.92 | 10.58 | 1,014 | 1,147 | 1,376 | 16.70 | 7.84 | 4,374 | 2,068 | 2,306 |
| | 7-pounder | 3.35 | 2.50 | 15.43 | 1,345 | 1,543 | 1,280 | 15.38 | 7.28 | 5,061 | 2,241 | 2,820 |
| | 3.74 inch | 3.74 | 4.63 | 24.03 | 1,543 | 1,444 | 1,453 | 23.81 | 12.3 | 13,954 | 7,085 | 6,869 |
| Italy | 2.76 inch | 2.96 | 1.20 | 9.76 | 893 | 904 | 1,319 | 20.60 | 8.50 | 4,230 | 1,771 | 2,459 |
| Prussia | 4-pounder | 3.27 | 1.10 | 9.37 | 639 | 992 | 1,210 | 18.70 | 7.35 | 3,507 | 1,374 | 2,133 |
| | 6-pounder | 3.78 | 1.32 | 13.89 | 948 | 1,135 | 1,084 | 16.40 | 7.51 | 4,085 | 1,851 | 2,234 |
| | 3.15 inch | 3.27 | 2.71 | 11.11 | 871 | 1,102 | 1,520 | 22.14 | 9.71 | 6,507 | 2,878 | 3,629 |
| | 3.54 inch | 3.47 | 3.31 | 15.34 | 992 | 1,190 | 1,458 | 22.50 | 11.38 | 9,761 | 4,881 | 5,380 |
| Switzerland | 3.15 inch | 3.15 | 2.85 | 12.22 | 959 | 1,036 | 1,097 | 17.88 | 8.55 | 4,736 | 2,277 | 2,459 |
| Sweden | 2.76 inch | 2.96 | 1.72 | 8.58 | 827 | 1,047 | 1,279 | 14.69 | 6.30 | 2,809 | 1,247 | 1,562 |
| Russia | 9-pounder | 4.21 | 2.71 | 24.38 | 1,336 | 1,173 | 1,060 | 20.40 | 10.70 | 8,315 | 4,526 | 3,789 |
| | 4-pounder | 3.42 | 1.36 | 12.63 | 723 | 1,014 | 1,009 | 15.91 | 6.49 | 2,747 | 1,103 | 1,644 |
| United States | 3.20 inch | 3.29 | 2.50 | 12.00 | 840 | 1,075 | 1,370 | 21.61 | 9.48 | 6,091 | 2,672 | 3,419 |
| | 3.20 inch | 3.20 | 3.00 | 12.00 | 840 | 1,075 | 1,518 | 24.4 | 10.7 | 7,763 | 3,405 | 4,358 |

*Hexagonal bore.

TABLE B.—*Details concerning modern and old Russian field guns, as regards their use on old and modern carriages.*

| | Gun. | Caliber, in inches. | Weight, in pounds. | | | | Initial velocity, in feet. | | | Living force, in foot-pounds. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Charge. | Projectile. | Gun. | Carriage. | Projectile. | Gun. | Gun and carriage. | Gun. | Gun and carriage. | Difference. |
| Russian | 4-pounder | 3.42 | 1.36 | 12.63 | 723 | 1,014 | 1,000 | 15.91 | 6.40 | 2,747 | 1,103 | 1,644 |
| | Ordinary | 3.42 | 1.36 | 12.63 | 723 | *434 | 1,000 | 15.91 | 10.00 | 2,747 | 1,808 | 939 |
| | 4-pounder | 3.42 | 4.52 | 13.10 | 900 | 1,014 | 1,500 | 21.00 | 10.40 | 7,410 | 3,651 | 3,759 |
| | Long range | 3.42 | 4.52 | 13.10 | 900 | *434 | 1,500 | 21.00 | 14.70 | 7,410 | 5,097 | 2,313 |
| | 4-pounder | 3.42 | 3.16 | 13.10 | 723 | 939 | 1,400 | 27.88 | 12.20 | 8,857 | 3,839 | 5,018 |
| | Cavalry | 3.42 | 3.16 | 13.10 | 723 | *434 | 1,400 | 27.88 | 17.48 | 8,857 | 5,531 | 3,326 |
| | 9-pounder | 4.17 | 2.71 | 24.38 | 1,336 | 1,173 | 1,060 | 20.40 | 10.70 | 8,315 | 4,526 | 3,789 |
| | Ordinary | 4.17 | 2.71 | 24.38 | 1,336 | *434 | 1,060 | 20.40 | 15.38 | 8,315 | 6,558 | 1,757 |
| | 9-pounder | 4.17 | 5.64 | 24.38 | 1,371 | 1,173 | 1,200 | 24.0 | 12.79 | 12,927 | 6,529 | 6,298 |
| | Long range | 4.17 | 5.64 | 24.38 | 1,371 | *434 | 1,200 | 24.0 | 18.20 | 12,927 | 9,348 | 3,579 |
| | 9-pounder | 4.17 | 5.64 | 24.38 | 1,371 | 1,080 | 1.200 | 24.0 | 13.48 | 12,927 | 6,912 | 6,015 |

*New.

TABLE C.—*Details concerning wrought-iron and steel field carriages.*

| | England. | | | Sweden, 3.0 inch. | Switzerland, 3.15 inch. | Italy, 2.96 inch. | Austria. | | Prussia,* 3.47 inch. | France. | | Russia. | | | United States, 3.20 inch. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 16-pounder. | 12-pounder. | Whitworth steel. | | | | Krupp steel. | New. | | 7-pounder. | 3.74 inch. | 4-pounder. | 9-pounder. | Common to both calibers. | |
| Angle of recoil† | 27° | 25° | 32° | 30° | 22° | 37° | 30° | 30° | 32° | 32° | 30° | 30° | 30° | 32° | 29° |
| | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *In.* |
| Height of axis of trunnions above the ground | 42.5 | 45.5 | 41.34 | 40.63 | 40.98 | 40.98 | 43.78 | 45.59 | 43.98 | 46.5 | 42.37 | 41.62 | 45.79 | 43.7 | 41.2 |
| Height of axis of axle above same | 29.9 | 29.9 | 28.74 | 29.37 | 28.35 | 25.00 | 27.00 | 26.62 | 25.23 | 29.53 | 29.81 | 27.44 | 27.44 | 27.44 | 28.5 |
| Vertical distance from the axis of trunnions to the middle of the axle, carriage unlimbered | 12.48 | 12.99 | 10.00 | 11.59 | 15.00 | 16.49 | 19.59 | 19.22 | 15.99 | 16.18 | 12.84 | 14.52 | 18.35 | 16.12 | 12.7 |
| Horizontal distance between same points, carriage unlimbered | ...... | ...... | 1.49 | ...... | 4.32 | 2.75 | ...... | 1.00 | 0.256 | 2.75 | 1.21 | ...... | 3.25 | ...... | 1.1 |
| Diameter of trunnions | 4.02 | 3.5 | 4.02 | 3.25 | 3.67 | 3.43 | 3.94 | 3.5 | 3.25 | 5.91 | 4.53 | 3.31 | 3.31 | 3.31 | 3.7 |
| Distance between trunnion plates | 12.5 | 11.49 | ...... | 10.25 | 10.00 | 7.99 | 10.5 | 10.22 | 8.24 | 10.7 | 13.19 | 9.00 | 10.5 | 10.5 | 9.6 |
| Exterior width of head of carriage | 17.53 | ...... | 14.77 | 13.78 | 15.7 | 12.24 | 13.82 | 14.2 | 13.23 | 17.53 | 18.00 | 12.28 | 14.2 | 15.99 | 13.6 |
| Exterior width of end of trail | 6.25 | ...... | ...... | 3.74 | 4.02 | 4.02 | 4.22 | 4.25 | 6.00 | 6.70 | 14.57? | 12.28 | 14.2 | 6.77 | 4.7 |
| Distance from axis of trunnions to beginning of convergence of cheeks | 27.00 | 30.99 | 22.00 | 17.00 | 6.61 | 27.51 | 16.00 | 15.75 | ...... | ...... | ...... | ...... | ...... | ...... | 6.0 |
| Width of cheeks— | | | | | | | | | | | | | | | |
| Maximum | 10.78 | 12.99 | 9.96 | 10.00 | 11.81 | 16.49 | 18.51 | 16.62 | 15.31 | 15.23 | 14.00 | 17.21 | 18.46 | 14.48 | 11.8 |
| Minimum | 4.17 | 5.12 | 4.25 | 4.49 | 6.46 | 4.06 | 4.14 | 4.26 | 3.35 | 6.5 | 4.49 | 7.48 | 5.01 | 4.02 | 5.6 |
| Thickness of cheeks | 0.26 | 0.26 | 0.70 | 0.26 | 0.15 | 0.19 | 0.30 | 0.23 | 0.26 | 0.31 | 0.47 | 0.26 | 0.26 | 0.26 | 0.31 |
| Thickness of angle-iron | 0.37 | 0.26 | ...... | 0.19 | 0.27 | 0.19 | ...... | 0.27 | ...... | ...... | ...... | 0.27 | 0.27 | ...... | ...... |
| Width of flange of angle-iron— | | | | | | | | | | | | | | | |
| Horizontal | 2.25 | 2.01 | ...... | 1.49 | 2.30 | ...... | ...... | 2.11 | ...... | ...... | ...... | 1.49 | 1.49 | ...... | ...... |
| Vertical | 2.25 | 2.01 | ...... | 1.07 | 3.00 | ...... | ...... | 2.11 | ...... | ...... | ...... | 1.49 | 1.81 | ...... | ...... |
| Width of flange of cheeks | ...... | ...... | ...... | ...... | ...... | 1.49 | 1.59 | ...... | 1.59 | 2.36 | ...... | ...... | ...... | ...... | 2.00 |
| Distance from center of lunette to end of trail‡ | 3.00 | —3.00 | ...... | +15.99 | —3.00 | —2.4 | —3.98 | —2.76 | —3.35 | —2.96 | ...... | +5.86 | +1.69 | +9.15 | —4.00 |
| Total length of cheeks | 100.31 | ...... | 88.27 | ...... | ...... | ...... | 93.7 | 96.5 | 81.5 | 98.51 | 95.56 | 97.01 | 100.35 | 90.46 | 95.00 |
| Axle body— | | | | | | | | | | | | | | | |
| Length | 48.5 | 48.5 | 50.00 | 38.27 | 35.43 | 44.77 | 47.98 | 51.97 | ...... | 41.62 | 36.02 | 41.25 | 41.25 | 41.97 | 43.5 |
| Width | 3.25 | 3.00 | 3.5 | 2.38 | ...... | 3.76 | 3.35 | ...... | ...... | 3.00 | 3.35 | 3.00 | 3.00 | 2.5 | 3.5 |
| Height | 3.5 | ...... | ...... | 2.88 | ...... | §5.38 | ...... | ...... | ...... | 3.00 | 3.54 | 3.00 | 3.00 | 3.25 | 3.5 |
| Diameter, in the middle | ...... | ...... | ...... | ...... | 3.66 | 3.76 | ...... | 3.94 | 3.54 | ...... | ...... | ...... | ...... | ...... | 3.75 |
| Diameter, at shoulder | ...... | ...... | ...... | ...... | 3.66 | 3.00 | 3.00 | 3.15 | 2.86 | ...... | ...... | ...... | ...... | ...... | 3.00 |
| Axle-arm— | | | | | | | | | | | | | | | |
| Length | ...... | 12.91 | ...... | 15.51 | 16.15 | (¶) | 12.01 | 10.28 | 13.5 | 16.49 | 16.49 | 16.00 | 16.00 | 16.00 | 12.5 |
| Diameter at shoulder | 3.00 | 3.00 | ...... | 2.13 | 2.54 | 2.18 | 2.3 | 2.28 | 2.00 | 2.84 | 2.84 | 2.76 | 2.76 | 2.3 | 3.00 |
| Diameter at end | 2.25 | ...... | ...... | 2.00 | .... | 1.63 | 2.3 | 2.25 | 2.00 | 1.97 | 1.97 | 2.11 | 2.11 | 2.3 | 2.5 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Track (from out to out) | 60.98 | 60.98 | 56.5 | 58.74 | 56.70 | 53.00 | 58.19 | 59.1 | 60.00 | 61.5 | 61.5 | 56.15 | 57.76 | ........ | 62.75 |
| Diameter of wheels | 60.00 | 60.00 | 55.5 | 58.74 | 56.7 | 50.00 | 54.00 | 52.69 | 55.5 | 59.06 | 58.9 | 54.92 | 54.92 | 54.92 | 57.00 |
| Number of spokes | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 14.00 | 14.00 | 12.00 | 12.00 | 12.00 | 12.00 |
| Diameter of nave— | | | | | | | | | | | | | | | |
| Large end | 5.00 | ........ | ........ | 7.33 | 7.48 | 4.14 | 5.71 | ........ | ........ | 10.00 | 3.47 | 8.5 | 8.5 | 8.5 | ...... |
| Small end | 4.00 | ........ | ........ | 5.99 | 6.61 | 3.15 | 2.52 | ........ | ........ | 8.26 | 3.00 | 7.48 | 7.48 | 7.48 | ...... |
| In the middle | 12.01 | ........ | ........ | 10.51 | 10.31 | 8.97 | 11.02 | ........ | ........ | 11.49 | 11.49 | 10.59 | 10.59 | 10.59 | ...... |
| Seats— | | | | | | | | | | | | | | | |
| Width | 14.02 | 14.02 | ........ | 17.00 | ........ | 16.49 | 12.00 | 16.49 | 15.51 | 13.5 | ........ | 17.00 | 17.00 | 17.00 | ...... |
| Depth | 17.51 | 17.51 | ........ | 17.51 | ........ | 16.49 | 15.75 | 15.79 | 13.23 | 13.23 | ........ | 19.02 | 19.02 | 19.02 | ...... |
| | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* |
| Weight without wheels but with implements | ........ | ........ | 758 | 758 | 763 | 723 | 741 | 794 | 704 | 1,030 | 882 | 831 | 866 | 732 | ‖715 |
| Weight with wheels | 1,345 | ........ | 1,012 | 1,047 | 1,054 | 911 | 1,074 | 1,190 | 1,155 | 1,481 | 1,407 | 1,164 | 1,202 | 1,056 | 1,075 |
| Weight of two wheels | ........ | ........ | ........ | 326 | 326 | 650 § | 333 | 397 | 362 | 452 | 525 | 315 | 315 | 315 | 360 |

* The carriage for the 2.76-inch rifle serves also for the 3.15-inch gun. In this case, in order to lighten it, they have omitted the seats. It weighs 1,080 pounds with wheels.
† The angle of recoil is the angle made with horizontal line by a right line drawn from the axis of the trunnions to the point of contact of the trail with the ground.
‡ The sign + refers to those carriages which are provided with a pintle plate; the sign — to carriages in which the trail is terminated by a lunette plate.
§ This includes the fillet.
‖ Without implements.

## COLONEL ENGELHARDT'S CARRIAGE.

(Description from the Revue D'Artillerie, August, 1877.)

(Plate I.)

This carriage is intended for the service of both the 9 pounder and 4-pounder (using trunnion-rings), and for the long-range guns recently designed. It is composed of two parts, the "body" of the carriage and the "train," united in such manner that the shock received by the first part from the trunnions of the gun is transmitted progressively to the second by means of an elastic compressor.

The body is formed of two cheeks, made of 0.26-inch plate, flanged along its entire periphery; the projecting edges thus formed take the place of the angle-iron heretofore used for re-inforcing the cheeks.

The cheeks are assembled by four transoms (*a*, *b*, *c*, *d*), two assembling-collars containing bolts (*m* and *n*), and a trail-plate (*p*). The width of the cheeks from out to out is 14.5 inch at the height of the trunnions and 7.5 inch at the trail.

Near the head of the carriage are the trunnion-beds, strengthened by bed-plates and covered by hinged cap-squares.

The first transom starts from the trunnion-bed, and, following the line *a a*, runs obliquely toward the axle, and is braced along the under edge of the cheek for a length of 8 inch. The upper part of this transom is cut away to make space for the gun. The second transom is also placed obliquely, following the line *b b* from the rear end of the trunnion bed-plate to the lower edge of the cheek; it is almost parallel to the first transom and is similarly cut out above for the gun.

The third and fourth transoms are placed along the lines *c c* and *d d* (vertical), and serve as transverse supports to a trail-chest. The last and first two transoms are riveted to the cheeks by their flanges; the third is not assembled in the same manner; the lower edge alone is flanged; the other edges are riveted, respectively, to the flanges of two re-inforcing side-plates, which furnish on the interior of the cheeks the slide for the cross-head, and to the flange of a plate above the trail, near the elevating apparatus; this last plate is cut away in front to make room for the elevating-rack, and its other three sides are bent down, the long sides over the cheeks, and the rear side against the third transom, to which it is riveted.

The cheeks are otherwise assembled by two bolts, furnished with *collar-transoms*, and by a trail-plate. One of these bolts (*m*) is placed near the elevating apparatus, and the other (*n*) at the trail, where it also serves to hold the front end of the trail-handle.

The trail-plate (*b*) is made of 0.26-inch plate and riveted to the flanges of the cheeks; its under part, prolonged toward the axis, contains an opening in which is imbedded a bronze lunette; this lunette has a groove in its under surface to assist the operation of limbering.

The bottom of the trail-chest, contained between the last two transoms and the cheeks, is formed of an iron plate, supported upon the lower flanges of the transoms and riveted with them to the cheeks at the corners. The cover is also made of thin plate, the long sides of which are bent down over the cheeks, while the short sides are furnished with hinges and hasps, so that the chest, which contains the cork buffer, may be opened and shut.

The elevating apparatus is composed of two screws like those in the

service carriage; the bronze nut is not attached to a special support, but is furnished with trunnions, which rest upon two bolsters (*q*) of an elliptical form, riveted to the cheeks by the first assembling-bolt and by two other bolts for each cheek. Of these trunnions, the right one has a hole in it, in which a screw-thread has been cut, and in which works a shank having a handle on the outside of the cheek; the other extremity of this shank rests upon a piece of steel (*s*, Fig. 7), provided with threads corresponding with those of the nut. The outer elevating screw is locked by this shank; it carries on top a circular rack (*t*) and an independent collar; the jointed handle (*u*) attached to the collar carries a tooth which must be geared with the rack, in order to turn it. The head of the inner screw is connected by a bolt to a movable fork, whose branches are each hinged to projections on the front transom.

The trail handspike swings back upon the carriage; it consists of a wooden handspike held by an iron socket, which takes the form of an arc toward the trail; in pointing, the handspike rests between two projections (*v v*) fixed on top of the trail-plate, and is held there by a key. After firing, the handspike is bent back over the cover of the trail-chest on to the shoulder of the support (*x*), where it is held by a hinged clasp.

There are two handles on the trail for handling it, and a steel spade, solidly bolted to the end of the trail, arrests the recoil by plowing through the ground; in hard ground the recoil is reduced to 7 inches.

The necessary iron hooks and rings are attached to the carriage to carry the sponges, shovel, bucket, and grape-box, one of the latter being carried for the 9-pounder and two for the 4-pounder.

The second part of the carriage, which is called the "train," is composed of the axle, the wheels, the movable cross-head, and the compressor.

The axle (*a*) rests in straps fastened by two bolts to the re-inforcing band under the cheeks. These straps and bands form slides sufficiently long to allow the axle a play in both directions (front and rear).

The axle is made of iron, is 2.5 inches square at the shoulder, while the axle body has the same width and is 3.5 inches high.

From the shoulder of each axle-arm starts a tie-strap (*b*), which runs to the middle of the cheek, and is there attached by an eye to the extremity of the cross-head (*f*); the cross-head works in the two slides cut for it in the cheeks and provided outside of the cheeks with rimbases, whose outer surfaces are parallel to each other; by this means the distance between the inner faces of the ends of the tie-straps is kept constant. The play between the axle-body and its strap is the same as that of the cross-head and its slide in the cheeks.

The axle, the tie-straps, and the cross-head form thus a trapezoidal combination, capable of moving backward and forward, to a certain extent, with reference to the cheeks.

Copper and leather washers are placed alternately upon the cross-head, between the ends of the tie-straps and the cheek rimbases, to weaken the effect of lateral shocks.

Upon the cross-head are wedged two bolts with looped heads (*h h*), which pass through the third transom and an iron plate, which contains between them the compressor, composed of seven plates of cork between two plates of oak. Screw nuts on the ends of these bolts serve to force the sliding combination toward the transom by compression of the cork.

At rest, the axle and cross-head should be retained against the rear face of their respective bearings. Since nuts do not unlock themselves, a double wrought-iron wrench is fitted to them, which prevents them

from turning, and is kept in place by a small pin attached to the inner plate.

The cork, before being used, should be boiled in a mixture of three parts (by volume) of water and one part of honey; then submitted to a pressure sufficient to reduce its height twenty per cent., and then coated with soap.

To form the compressor, they arrange together three times in succession two pressed cork plates and one thin iron one, and then a seventh cork plate; the iron plates must extend 0.1 inch beyond the cork to protect it from being broken. The compressor thus formed is about 7.0 inches high between the plates, the pressure of the nuts reducing this to from 3.3 inches to 3.5 inches. This only occurs when the gun is ready for firing. Then, care must be taken that the cork does not lose its elasticity, and to observe the motion of the axle in its straps. The extent of this movement should not exceed 2.0 inches.

The wheel selected for this carriage is the service wheel, with a nave slightly shortened, and furnished with a cylindrical nave-box, which projects slightly and is so arranged as to hermetically seal the end of the axle-arm.

The axle and tie-straps support two seats for cannoneers, with foot-rests so hinged as to swing back to the rear; each seat is mounted upon three cork springs, formed, like the compressor, of alternate rings of cork and iron plate, held in a small iron case, a bolt running through the rings (at their centers) and the upper end of the case.

The two front supports are fastened to the axle, the rear one to the tie-strap; the rear one for the left seat terminates below in a bucket-hoop.

In firing, the cheeks commence to recoil sooner than the axle and wheels, which only receive the shock after it has been reduced by the compressor; in consequence of the reaction due to the elasticity of the cork, the "slide" (wheels, axle, and cross-head) at the end of the recoil returns to its original position.

The new carriage permits of 20° elevation.

## DESCRIPTION OF THE ENGELHARDT FIELD CARRIAGE, LIMBER, AND CAISSON.

[From the Revue d'Artillerie, July, 1878.]

### THE CARRIAGE—(Plate II.)

Besides the substitution of rubber for cork in the compressor and elsewhere, the most important improvement over the model described August, 1877, consists in the strengthening of the spade which is attached to the trail. This spade, where it plows the ground, is now 1.8 inches thick, and is supported its entire length by the end of the trail, to which it is attached by three bolts, two above and a larger one in the middle. The length of the projection beneath the trail has also been reduced, as shown in Fig. 1.

The elastic compressor is now made of rectangular plates of rubber (*a*, Fig. 2), (whose corners are rounded to prevent tearing), with a hole of the same shape in the center. Along its smaller sides are made semicircular recesses in which fit bolts (*h*) with looped heads. Between the two plates is a diaphragm of iron plate fitted on both of its faces with guides riveted on, which hold it steady midway between the plates; the head of the cap (*g*) has similar guides riveted on.

This arrangement of guides, and bolts with looped heads, is intended to support the plates and prevent abnormal disfiguration under the violent strains to which it is subjected.

The total compression of the rubber plates is, under fire, 1.5 inches for the 4 pounder, and 2.1 inches for the 9-pounder long-range gun.

Under ordinary circumstances, rubber would be unsuitable for such use, for it hardens at low temperatures and loses its elastic properties; but Colonel Engelhardt has discovered and patented a process by which perfectly pure rubber, subjected to a certain process of vulcanization, is unaltered by temperatures as low as 25° below zero.

Rubber washers (*m*) are also placed at the extremities of the movable cross-head (*f*), between the collar formed by the brace (*b*) and the nut of the cross-head, to weaken the lateral shock experienced here. Finally, another rubber washer is placed on the axis of the stop for the pointing-lever, between the stop and the lever, to soften the shock received in firing; the lever is also considerably raised, which makes the position of the gunner less fatiguing; and on the end of it is a horizontal bar 15.7 inches long, on which the gunner leans.

The cork springs which supported the seats of the carriage have been replaced by rubber springs (Fig. 3) formed of a simple cylindrical tube (*a*) bearing at each end upon the conical head of a bronze collar (*b*), and traversed by the bolt (*c*), which supports the plate for the seat, and passes freely through the bronze collars and into the support (*f*) which is fixed to the axle or brace.

The cheeks of 0.26 inches flanged plate are 90.5 inches long, measured along the lower edges, which is rectilinear; their width, measured normal to this edge is 14.5 inches in rear of the trunnions (maximum); 9.5 inches at the seat of the elevating apparatus and slide, and only 4 inches at the center of the trail (minimum).

The flange, extending along the entire periphery, is 2 inches wide, gradually reducing to 1.5 inches at the bottom of the trail.

The total length of the iron axle is 76.3 inches, 42 inches of which is taken up by the axle body. Near the middle of the axle body are two projections (Fig. 4, Plate III), against which the cheeks rest. The width of the axle body is 2.5 inches; its height, which varies from 3 inches to 3.2 inches between the shoulder and the projection, is 3.5 inches in the middle; its upper face is horizontal, and the additional thickness at the projections is obtained by a suitable inclination of the lower face between the projections and the shoulders. The axle arms are 2.8 inches in diameter at the larger end, and 2.1 inches at the small end, with a pitch of 0.3 inch for its entire length, which is 17.2 inches.

The axle is, at rest, 31.2 inches from the axis of the cross-head; the straps which unite the two are of iron plate, 2.4 inches high, with a mean thickness of 0.5 inch near the axle, and 0.6 inch near the cross-head; the cross-head is made of steel, total length 18 inches, 2 inches wide, and 1.5 inches high.

The shank of the bolts with looped heads is 1.1 inches in diameter; the head which embraces the cross-head is 1.5 inches wide and 0.6 inch thick. The stay-plate which supports the compressor is 0.5 inch thick. As for the compressor itself (dimensions given, Fig. 2), each composing plate is 2.5 inches thick; the diaphragm is a plate 0.12 inch thick, and the guides made of 0.26 inch plate.

The springs for the seats of the carriage are 3 inches in height, 2.5 inches exterior and 1 inch interior diameter. There are keys for all nuts used on the carriage, limber, and caisson.

## LIMBER—(Plate II).

The frame (Fig. $6^2$), shaped like a shield, is composed of two side-rails meeting in a point at the rear, and of a fixed splinter-bar forming the front of the frame; stiffness is secured besides by two cross-pieces; all of these pieces are made of strong angle-iron, the horizontal flange uppermost. Their joints are secured by pieces of angle-iron, and to prevent the outer parts of the splinter-bar from bending, the ends are fastened to the side rails, a little in advance of the first cross-piece, by iron braces. "Steps" are attached to both ends of the splinter-bar, as well as four permanent trace-hooks, each closed by a movable catch. At the middle of the bar is a bridle (*t*), through which passes the pole, the pole-socket fitting in between two ears (*t*) attached to the front cross-bar, where it is held by a key-bolt; the small end of this bolt, jointed to the shank by a hinge, serves to keep the bolt in place. At the end of the frame the side rails are united by two assembling-plates, one above and the other below, upon which is bolted the pintle; there are projections (*a*) on the lower plate, through which it is riveted to the side rails, and the double pintle nut rests against a ring washer (*b*) which carries the locking chain (Fig. $6^1$).

On the right and left of the pintle are two handles, which probably are intended as points of attachment for a system of drags for the limber.

The same axle is used for the limber and caisson (Fig. 5, Plate III): the body of rectangular cross-section is 2.8 inches high by 2 inches wide: there are large circular shoulders on the ends, which fit into corresponding recesses in the wooden naves of the wheel; these latter are 55 inches in diameter; they are kept on by a washer and linch-pin, secured by an elastic thong of heavy iron wire.

The axle arms, though a little shorter, have the same dimensions as those of the carriage; however, the *pitch* is 0.4 inch.

At right angles to the frame two ribs are riveted onto the axle for the purpose of attaching it to the suspension-springs, as well as to serve as guides for the "plates" which support the body of the limber. The body of the limber rests then indirectly upon the axle, but through the medium of springs placed below it.

The suspension is obtained as follows: Each side rail is supported by two triangular braces (*e*) made of 0.26 inch plate, placed on the right and left of the axle, with space enough between their vertical edges for the axle to pass through; these same edges are reinforced on the inside and out by heavy bands (*f*), which form the *supporting plates*, between which fit precisely the ribs on the axle, which prevent lateral displacement by the projections which bear against the "plates"; the ends of the outside re-inforcing bands have threads cut on them, upon which is firmly bolted the flange (*g*), of an elongated, hexagonal shape, with projections between which are held the triangular supports (*e*); these supports are bound to the middle of each cross-piece by braces (*h*, Fig. 6).

The lower face of the flange (*g*) contains a longitudinal slit by which it rests upon a projection on the upper surface of the spring-box. The spring (Fig. $6^3$) is of rubber and in the shape of two frustrums of cones, united at their larger bases; a ring of iron fastened at the height of their common base protects the rubber spring, which is traversed along its axis by the suspension bolt (*i*), pivoted to the lower rivet of the axle-ribs. The spring rests at bottom on a circular plate, and supports the weight of the body of the limber by means of the flange (*g*), and bronze cover (*j*), to which is attached the projection upon which the flange

presses. A light wooden box attached only above protects the rubber from bruises and from exposure. Leather washers are placed between the flange (*g*) and the axle-ribs to lessen the effects of shocks.

The limber carries a chest riveted upon the cross-bars and fastened besides to the one in front by two bands (*l*), and to the rails by two side-bands (*m*), ending at bottom in rings to which different ropes are attached under the carriage by means of straps.

The chest, made of 0.06 inch plate, is surmounted by a rail running round the back and sides. The pieces are joined together without angle-iron, by simply bringing the edges together. A frame of iron plate, upon which are riveted the side bands, borders the rear of the chest, which is completely open, and shows only an upright in the middle, shaped like the letter U, which receives the vertical hinges of the doors for the two half-chests. These doors are strengthened by a frame with a *turned back* edge which embraces the small side of the chest, where the door is closed, to mask the joint and keep out the rain; to lock the chest, each door is provided with a hasp which locks into a swivel-key. Should the key be broken, the doors can be fastened by straps passing through the rings (*o*).

An ax (*n*, Fig. $6^1$) is carried on the side of the chest, and two pick-axes are places on the lid of the piece, one against each of the small sides, the handles attached by straps to the uprights of the rail.

The chest (Fig. 6 and $6^4$) is divided by the U-shaped upright into two half-chests, allowing a space between them equal to the width of the upright; each half-chest is then itself subdivided by partitions of peculiar construction into six divisions, each containing one loading case. Ribs above and below (*q*, Fig. 6), which also serve as guides when inserting or removing the cases, are made of 0.06-inch plate, bent into a T-shape (Fig. 7), and riveted respectively to the bottom and under the lid of the chest. The middle ribs (*r*), which also support the cases of the upper tier, are formed of two similar pieces joined at their bases, the upper one grasping the lower by its overlapping edges (Fig. 8); at their two extremities enough play is left between the plates to admit their being adjusted together, and their being riveted on one side to a simple longitudinal support attached to the front of the chest, and on the other to a band of strong plate fastened by projections at right angles to the rear of the chest against the small side and the U-shaped upright.

The six lower divisions thus obtained are intended each to receive a projectile (Fig. 13, Plate III); the six upper divisions, of less height, receive charges placed in leather boxes (Fig. 14), arranged in the inside into as many cylindrical vertical pockets as there are cartridges to be contained.

In front of the chest, the limber carries a wooden box attached to each side-rail by two straps (*u*) prolonged below to form large hoops, to carry spare ropes and straps. Only the inclined part on top of the box is movable, and this forms the lid, closed by a hasp and key; it also serves as a foot-board for the cannoneer mounted upon the chest, and consequently is covered with a thin iron plate. The box contains different utensils and spare parts; the box of the limber contains especially the hausse, instruments, and a monkey-wrench.

The leading horses, instead of being attached directly to the traces of those in rear, are hitched to a swing-tree attached to the end of the pole, which is here strengthened by plates above and below, and by a collar (Fig. 10). The hook for the swing-tree is closed by a movable ing, and secured by a bolt which forms part of it, and passes through and through the end of the pole and both plates, a little in rear of the

collar. That the wheel horses may back the carriage, a large ring is attached to the end of the pole through which pass two smaller rings, carrying each a hook.

CAISSON.—(Plate III.)

The body of the caisson, very similar to that of the limber, is composed of two side-rails connected by three cross-bars (the middle one a little in rear of the axle), and of a double middle rail, formed of two half rails jointed to the cross-bars. The cross-bars are united with the rails by angle-iron, except the connection of the middle rail with the front cross-bar, which is effected by a plate on the cross-bar ($a$, Fig. 11[3]). The body is then suspended from the axle as in the case of the limber, braces connecting the triangular supports to the middle rail.

A bronze lunette, like that of the carriage, is formed in a re-inforcing plate at the end of the middle-rail. A movable handle ($b$) is used for "limbering" and "unlimbering"; the bolt, which serves as its axis, passes through a ring, to which is attached the brace ($d$) of the foot-rest. Finally, the end of the middle-rail carries a hook (like a trace-hook, but smaller), in which is attached the ring of the locking-chain when "limbered."

The foot-rest is fixed upon two supports ($c$), movable about their joint with the middle-rail near the front cross-bar; it is also held by the movable trace ($d$), which can be disengaged from the bolt on which it rests; this will allow the foot-rest to be lowered on to the middle-rail and the chest to be opened.

There are eight loops ($f$) attached to the caisson, two under the side-rails, two under the front cross-bar, and one under each side of the middle-rail, between the two cross-bars, for carrying tools, cooking utensils, &c. A large stirrup ($h$) under the rear of the left side-rail receives a large smith's hammer, the handle of which is tied by a strap to the ring ($g$) placed under the middle of the rear cross-bar, and the ears ($l$), with their key and spring-catch, attached under the rear of the right-rail, carry the lifting implement, screw or lifting-jack, used in greasing the wheels. Iron steps are fastened to the front of the side-rails for convenience in mounting and dismounting cannoneers.

The angle of turning for the caisson is 80°. The chest for the caisson is similar to that of the limber, but has twice its capacity, the center of gravity being placed considerably in front of the axle. It is sustained and held laterally by angle braces ($j$, Fig. 11), the front one terminating below in large hooks, to which are attached the loose ends of the arrangement for "checking" the wheel carried by the limber. The chest is, besides, riveted to the body of the caisson, upon which it rests by means of wooden brackets. A large partition divides it into front and rear chests. The chest is shorter than that of the limber by the width of the U-shaped upright, which has been replaced by a simple double plate (Fig. 12). Both the front and rear of the chest consist of a simple door, working upon horizontal hinges below, and fastened by three catches, two of which are attached to the door and fastened to the sides, and the third attached to the cover and fastening to the door itself.

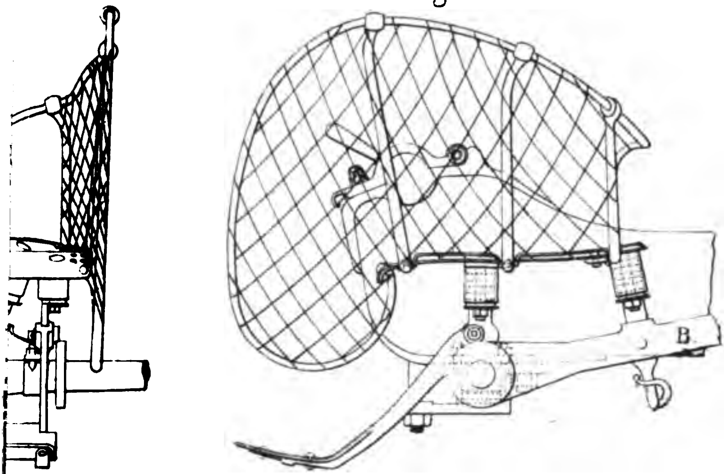
The projectiles are arranged in special sheet-iron skeleton cases, not only to facilitate loading and unloading the chests, but to protect the projectiles in transportation. The case is in the form of an elongated parallelopipidon; it is divided into two unequal parts by means of a partition ($k$), all of the edges of which, bent over at right angles, form overlapping flanges which bind together the box. The angles of the large

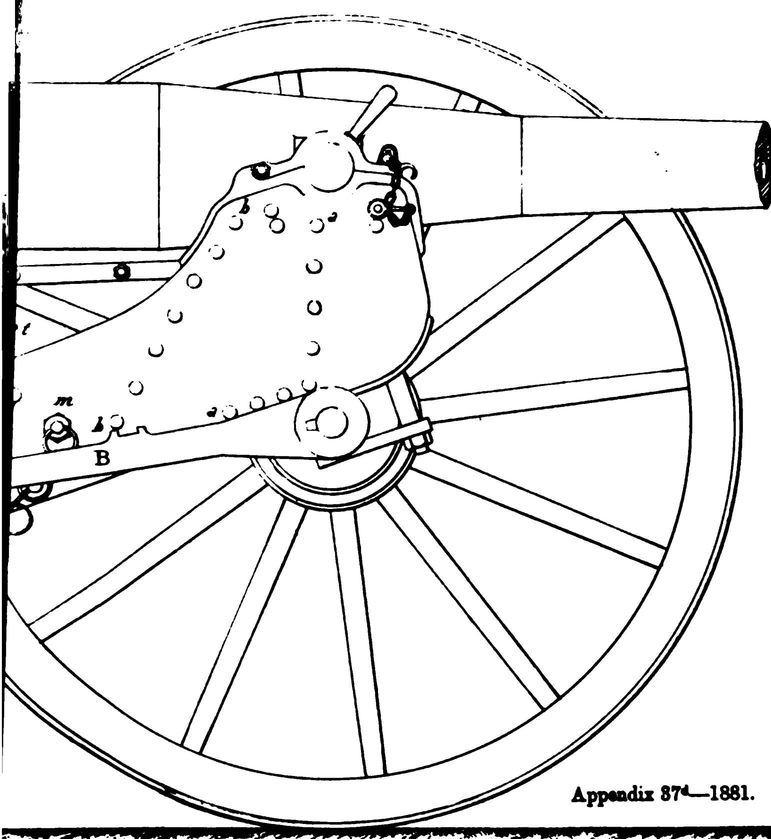
faces are stiffened by ties and angle pieces ($l$); the separation of the small sides is regulated by two V-shaped bands ($m$); by four rods ($n$), two above and two on the sides; and by two bottom plates, one in each half-case. The base cups (for projectiles) are fixed upon the bottom plates by three wood-screws each. Each case contains five 4-pounder or three 9-pounder projectiles; the half-cases holding in the first instance two and three projectiles; in the second, one and two. The steadiness of the projectiles is obtained by means of clamps which embrace them at the junction of the head with the body (of the projectile), and which are fixed to the braces ($n$) of the long sides; on one side this brace is composed of two parts swinging about a hinge attached to the division piece ($k$) and fastening by a latch to the adjacent small side. Either part of this brace can therefore be unlatched and swung back, giving access to whatever projectiles are needed. The clamps attached to the other (fixed) brace are cut to a suitable shape to receive the projectiles; those, on the contrary, which are attached to the swinging brace are flat, but carry on their points small elastic buttons, which rest against the projectiles.

| | 4-pounder. | 9-pounder. |
|---|---|---|
| Number of shots contained in chest of limber | 30 | 18 |
| Number of shots contained in chest of caisson | 60 | 36 |
| Total for gun followed by its caisson | 120 | 72 |

| | Horse artillery. | Mounted batteries. |
|---|---|---|
| 4-POUNDER. | *Pounds.* | *Pounds.* |
| Weight of carriage without wheels | 776 | 776 |
| Weight of two wheels | 306 | 306 |
| Total weight of gun mounted, and implements | 1,858 | 2,094 |
| Weight of limber empty, without wheels or ammunition chest | 723 | 723 |
| Weight of empty chest | ............ | ............ |
| Weight of limber complete, ready for service | 1,841 | 1,951 |
| Total weight of piece and limber | 3,699 | 4,045 |
| Total weight of piece and limber with five cannoneers mounted | ............ | 4,947 |
| Weight of caisson without limber, wheels, or chest | 826 | 826 |
| Weight of caisson (without limber) loaded ready for service | 2,564 | 2,707 |
| Weight of caisson complete (with limber) | 4,405 | 4,658 |
| Weight of caisson complete with cannoneers mounted | ............ | 5,015 |
| Weight drawn by one horse: | | |
| Piece (six horses) | 617 | 675 |
| Piece with cannoneers | ............ | 825 |
| Caisson (six horses) | 752 | 787 |
| Caisson with cannoneers | ............ | 908 |
| Caisson (four horses) | 1,129 | 1,182 |
| Caisson with four cannoneers | ............ | 1,362 |

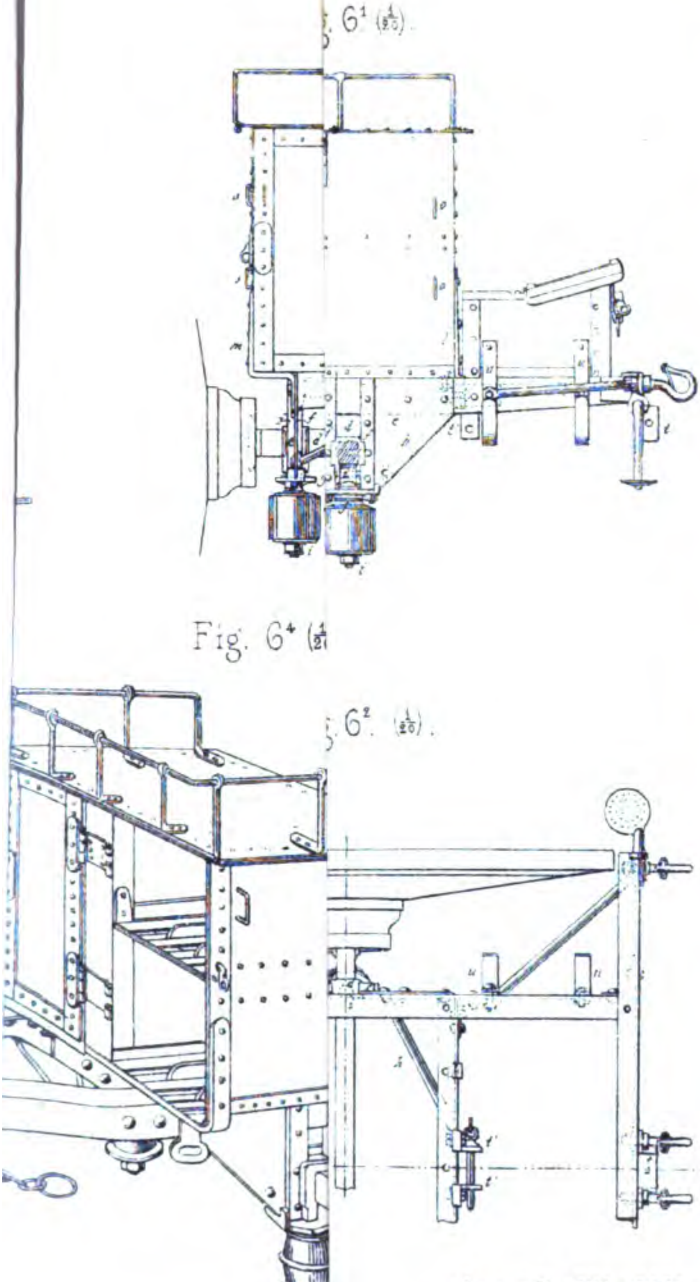
Fig. 4.




Appendix 87d—1881.

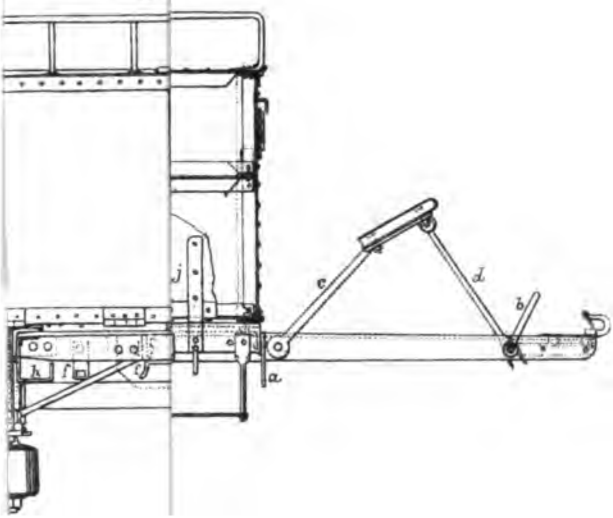
PLATE II.




Appendix 37ᵈ—1881.

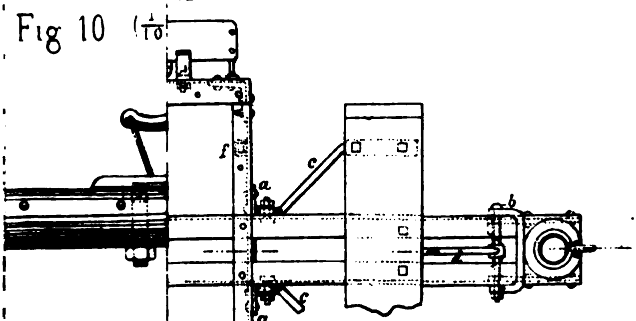
PLATE III.

Fig 1 ($\frac{1}{10}$)




($\frac{1}{10}$)

Fig 10 ($\frac{1}{10}$)



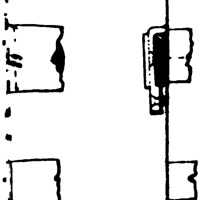
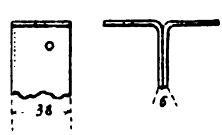



Fig 12.




Appendix 37$^{d}$—1881.

## APPENDIX 37*f*.

### ?ROGRESS REPORT ON THE CONSTRUCTION OF FOUR 12-INCH BREECH-LOADING CHAMBERED RIFLES.

(One plate.)

These rifles, which are all to be made upon the same plan, are to consist of a cast-iron body or casing lined with a steel-jacketed coiled wrought-iron tube inserted at the breech, the jacket of the tube being prolonged to the rear, and adapted for the reception of the breech-mechanism which is to be made after the Krupp system.

The breech of the casing is to be re-inforced with a steel breech-band. A contract for their fabrication was made with the South Boston Iron Company, under date of October 15, 1880.

The terms of this contract require the South Boston Iron Company to cast the casings of these rifles from cast-iron of the standard quality prescribed by the Ordnance Department for the manufacture of heavy guns, and to do all the work of finishing, fitting, and assembling the various parts.

In another contract with the same party, dated September 28, 1880, they are required to furnish the necessary steel-parts for the rifles, which are to be equal in physical qualities to the steel used in the fabrication of the 8-inch breech-loading rifle, described in the report of the Chief of Ordnance for 1878. The coiled wrought-iron tubes are to be furnished by the United States and fabricated at the West Point foundry. On account of the necessity of preparing the plant to be used, but little progress has been made at the present date (August 10, 1881) towards fulfilling the contract for the fabrication of these rifles. It may be summed up as follows:

The core-arbor and flask for making the molds of the casings have been cast, and are being finished and prepared for use. The pig-iron to be used in casting has been purchased and delivered at the foundry. Under the contract for furnishing the steel, all the required parts, with the exception of one jacket, or breech-receiver, and three breech-bands, have been procured and delivered from the works of Firth & Co., at Sheffield, England.

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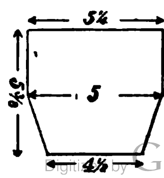
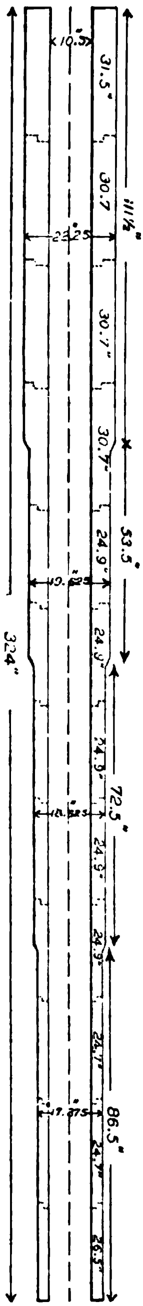
### PROGRESS REPORT OF TUBES FOR FOUR 12-INCH BREECH-LOADING RIFLES, NOW BEING CONSTRUCTED AT THE WEST POINT FOUNDRY.

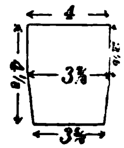
The tube iron was obtained from the Ulster Iron Works in lengths and sizes as follows:

No 1. { 64 bars 11′ $1\frac{1}{2}$″ long; cross-section
4 bars 12′ long; same cross-section.






No. 2. 24 bars 15′ long; cross-section




No. 3. 36 bars 17′ 8″ long; cross-section 3⅜″ square.
No. 4. 36 bars 16′ 8″ long; cross-section 3″ square.
Specimens 3″ long between shoulders and 0″.567 in diameter were tested with the following results:

| Size of bar as numbered above. | Specimen. | Tenacity. | Elastic limit. | Extension, per inch, at rupture. | Reduction of diam. at point of rupture. |
|---|---|---|---|---|---|
| | | *Pounds.* | *Pounds.* | | |
| Number 1 | 1 | 47,500 | 23,000 | 0.273 | [illegible] |
| Do | 2 | 47,500 | 22,000 | 0.302 | [illegible] |
| Number 2 | 1 | 48,500 | 24,000 | 0.296 | [illegible] |
| Do | 2 | 48,500 | 26,000 | 0.286 | [illegible] |
| Number 3 | 1 | 49,500 | 26,000 | 0.319 | [illegible] |
| Do | 2 | 48,500 | 25,000 | 0.315 | [illegible] |
| Number 4 | 1 | 48,500 | 25,000 | 0.291 | [illegible] |
| Do | 2 | 48,500 | 26,000 | 0.294 | [illegible] |

The 68 bars of No. 1 were united in sets of four, each forming 17 bars, the longest of which was intended as a "dummy" for use in the work, but not to itself form part of any of the tubes.

The remaining bars were united in sets of three each making the number of coiled sections for each tube as follows:

Four sections of 5¼″ × 5⅝″ bar.
Two sections of 4″ × 4⅛″ bar.
Three sections of 3⅜″ square bar.
Three sections of 3″ square bar.

These twelve sections were united as shown in the marginal sketch.

In consequence of the length and weight of these tubes very considerable alterations had to be made to the plant: the press-furnace had to be entirely rebuilt, new cranes erected, and old ones strengthened; new welding pots and cheeses were also cast; but the different processes in the fabrication were identical with those heretofore described in the reports of the construction of other coiled tubes.

The welding was completed on the 22d of September, and the tubes at once transferred to the finishing shop to be bored and turned.

An experimental carriage, very similar in construction to that described in the report of the Chief of Ordnance for 1877, pages 657–661 for the 12.25-inch muzzle-loading rifle, is now being fabricated under a contract with C. H. Delamater & Co., of New York, for the first of the four 12-inch breech-loading rifles fabricated. Both top-carriage and chassis are to be of wrought-iron, and box-built. The plan of construction is briefly as follows:

The top-carriage to be formed of two cheek-pieces, strongly connected by bolts and transoms; each cheek being composed of two plates of rolled iron riveted to an iron frame, and further strengthened by inside struts. The chassis to be similarly constructed, except that a top and bottom rail with a shoe-plate fastened by rivets and angle irons, are to be used for uniting the rail-plates, instead of a frame.

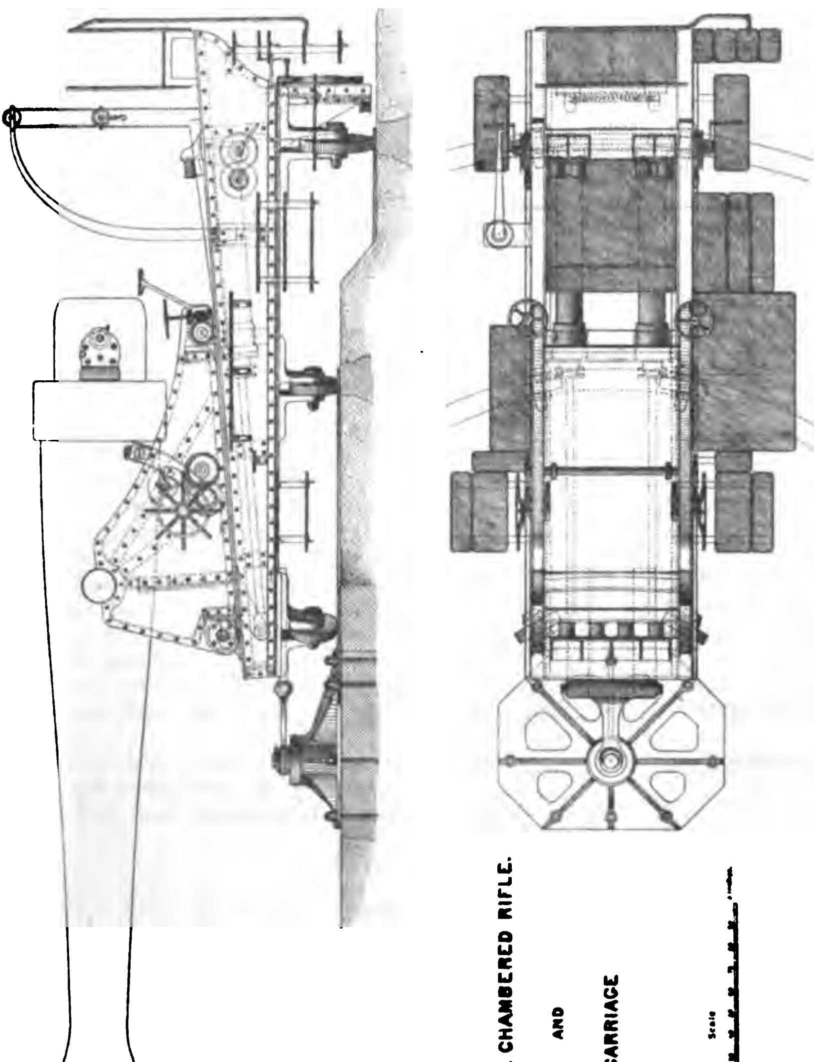
The general arrangements for traversing, elevating, and running the gun out of battery, loading, &c., are indicated on the plate. The recoil is to be overcome by means of two hydraulic buffers, the cylinders of which will be of bronze, and be attached to the chassis in rear of the gun.

It has been customary in the United States service with muzzle-loading guns to place the cylinders, both hydraulic and pneumatic, at the front end of the chassis; but in this case, where the gun is to be loaded from the rear, the cylinders are so disposed as to admit of the placing of a platform on the chassis in rear for the use of the cannoneers in loading.

The contract for this carriage was entered into on the 20th of July, 1881, and the work of fabrication is to be completed within eight months from that date.

A very solid platform of masonry and concrete has been laid at the Proving Ground, Sandy Hook, for use with this carriage and its gun.

The total estimated weight of the top-carriage and chassis is 67,431 pounds.



12 INCH B. L. CHAMBERED RIFLE.

AND

CARRIAGE

Scale

Appendix 37'—1881.

# APPENDIX 37g.

## PROGRESS REPORT OF A 12-INCH BREECH-LOADING CHAMBERED RIFLED HOWITZER.

(One plate.)

### PRELIMINARY REMARKS.

On the 27th of December last a contract was entered into with the West Point foundry to convert one 15-inch smooth-bore Rodman gun into a 12-inch breech-loading chambered rifled howitzer on the plan adopted in the case of the 8-inch breech-loading rifle described in the report of the Chief of Ordnance for 1878. The terms of this contract require the furnishing of a coiled wrought-iron tube and the necessary steel-parts which are to equal in physical qualities the tube and steel used in the construction of the 8-inch breech-loading rifle, as well as an equal excellence in the work of finishing, fitting, and assembling the different parts.

### DESCRIPTION.

Excepting the necessary changes in the dimensions of the various parts and the addition of the muzzle-band, the description of the howitzer does not differ from that of the 8-inch breech-loading rifle referred to, and it is therefore unnecessary to do more than enumerate the principal parts.

1st. The cast-iron casing formed from the 15-inch smooth-bore Rodman gun by cutting off the breech and muzzle so as to leave a length of 120 inches, and by boring to the requisite diameters to receive the tube and jacket.

2d. A united coiled wrought-iron tube and steel jacket inserted into the casing from the rear, the former with a play and the latter with a shrinkage.

3d. The steel breech-block and parts working in the prolongation of the jacket to the rear of the casing.

4th. The steel breech and muzzle bands.

### FABRICATION.

#### THE TUBE.

The tube was made of Ulster tube-iron. Specimens of the iron used were tested with the following results:

| Specimens. | Length between shoulders. | Area of cross section. | Tenacity per square inch. | Elastic limit. | Extension per inch at rupture. | Remarks. |
|---|---|---|---|---|---|---|
| 4″ × 3″.85. | *Inches.* | *Inch.* | *Pounds.* | *Pounds.* | *Inch.* | |
| Hexagonal bar... | 3.00 | 0.2525 | 47,500 | 26,000 | 0.284 | A. Quality for rear sections. |
| 2″.75 square bar. | 3.100 | 0.2507 | 49,500 | 25,000 | 0.3016 | A. Quality for front sections. |

The tube was formed of four coiled sections, butt-welded together in the usual way, with addition in rear of a short carefully-forged section, about 5 inches long, designed to contain the seat for the gas check.

The tube was then bored, chambered, and rough turned, and subjected to a water test of 180 pounds to the square inch.

### THE CASING.

The gun selected for the conversion was 15-inch muzzle-loading Rodman gun, No. 80, manufactured at the South Boston foundry in 1865. It was placed in a lathe and a cut first made through the chase at a distance of 82.73 inches from the axis of the trunnions. The gun was then reversed in the lathe and the breech cut off at a distance of 37.27 inches from the same axis. Work was then stopped to await alterations to the lathe in which the casing was to be counterbored.

### THE STEEL.

The steel for the breech-receiver, breech-block, breech and muzzle collars, was obtained from Firth & Sons, of England, and in shapes as shown on Plate II.

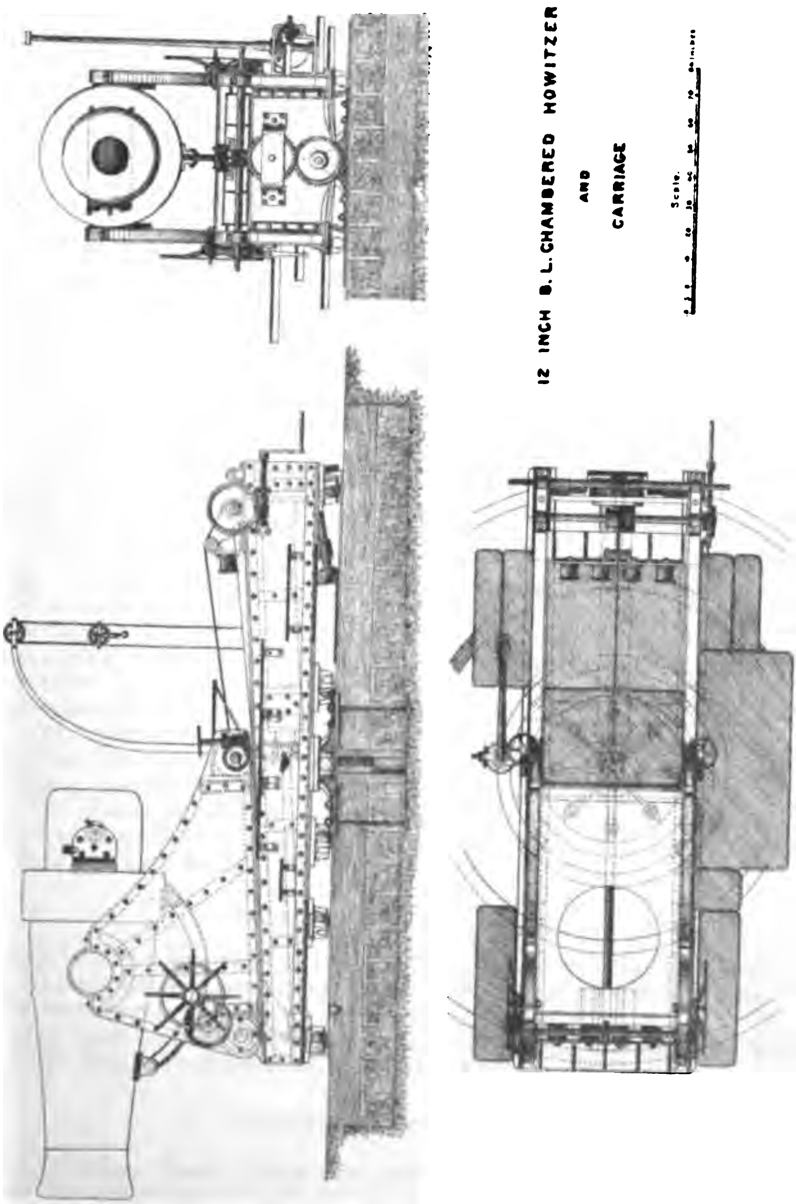
At the end of the fiscal year the breech-receiver was in the lathe boring.

The carriage for this gun is shown on Plate I. It is of wrought-iron, box-built, of generally similar construction to the experimental carriage for the 12-inch breech-loading rifle, described under the progress report on the fabrication of those guns. It differs from the 12-inch rifle carriage in the apparatus provided for traversing, and running the piece out of battery. (See plate.)

The chassis is a center pintle, and there is but one hydraulic cylinder employed. The height of the top-carriage is such as to admit of a maximum angle of 75°.

The contract for this carriage was entered into with C. H. Delamater & Co. on the same date as that for the 12-inch breech-loading rifle carriage, and the time allowed for its completion is the same.

The total estimated weight of the top-carriage and chassis is 32,246 pounds.


12 INCH B. L. CHAMBERED HOWITZER
AND
CARRIAGE
Scale.

## APPENDIX 37*h*.

### PROGRESS REPORT ON "PLANT" FOR THE FABRICATION OF 12-INCH BREECH-LOADING RIFLES AT THE SOUTH BOSTON FOUNDRY.

In connection with the contract for four 12-inch breech-loading chambered rifles, two contracts were made with the South Boston Iron Company for furnishing the necessary plant for their fabrication, one for "permanent plant," dated October 14, 1880, and one for "movable plant," dated October 19, 1880.

The contract for permanent plant requires the erection at the South Boston foundry of a shop building and foundations of masonry therein for two lathes of not less than 80 feet in length, and the laying of suitable tracks for a traveling crane, and the trucks required for moving the guns; and also the erection in the foundry-building of an elevated pool or basin for use in casting. The latter requirement was subsequently modified, upon the application of the South Boston Iron Company, so as to authorize instead the remodeling of one of the foundry pits, by increasing its depth sufficiently to admit of the castings for the casings of the rifles being made by running the metal directly from the furnaces into the mold.

The contract for movable plant contains the following requirements, viz: That one large gun lathe be furnished of sufficient capacity to turn and bore the cast-iron casings for the 12-inch breech-loading rifles, together with all the tools and appliances required for its proper working; that such alterations, repairs, and additions be made to a gun lathe to be furnished by the United States as may be necessary to fit it for the same class of work to be done by the new lathe; that a traveling crane be furnished with a power to lift at least ten tons; that the lathes, when finished, be set up upon the foundations erected for them in the shop building specified in the contract for permanent plant; and that the crane be placed in position upon tracks in the same building.

The progress made towards the fulfillment of these contracts at the present date (August 10, 1881) is as follows:

#### PERMANENT PLANT.

The shop building has been finished in accordance with the specifications of the contract and the foundations for the lathes completed. The tracks for traveling crane and trucks are being laid.

The foundry-pit has been sunk to a depth of 40 feet, and lined with a tank of boiler iron. To finish it a lining of brick remains to be laid inside the tank.

#### MOVABLE PLANT.

All the principal parts of the new lathe, and the most of those required for the extension and alteration of the old one, have been cast, and the work of finishing and fitting is being pushed forward as rapidly as practicable.

The traveling crane has been finished in accordance with the specifications of the contract.

## APPENDIX 37i.

REPORT OF RESULTS OBTAINED IN THE MECHANICAL TESTS OF THE STEEL USED AT THE WEST POINT FOUNDRY IN THE CONVERSION OF SMOOTH-BORE RODMAN GUNS INTO BREECH-LOADING RIFLES.

On the 1st and 27th of December last, the West Point foundry entered into contract with the United States to furnish the steel parts required for use in converting five 10-inch smooth-bore Rodman guns into 8-inch breech-loading rifles; two 15-inch smooth-bore Rodman guns into 11-inch breech-loading rifles; and one 15-inch smooth-bore Rodman gun into a 12-inch breech-loading rifled howitzer; and it was stipulated that all these various steel parts should equal in physical qualities the Whitworth fluid-compressed steel employed in the fabrication of 8-inch breech-loading rifle No. 1, converted at the South Boston foundry.

The following general summary was obtained by taking a mean of the results obtained by testing, on the machine of the ordnance agency, two specimens, 6 inches long between shoulders and 0.653 inch in diameter, taken from the breech receiver of this rifle, and consequently exhibits the standard assumed:

| | |
|---|---|
| Specific gravity | 7.8526 |
| Ultimate resistance to extension ....pounds.. | 83,500 |
| Elastic limit ....pounds.. | 32,500 |
| Extension per inch at rupture ....inch.. | 0.20516 |
| Hardness | 16.254 |
| Hardness of copper | 5.000 |

The founders ordered this steel from Thomas Firth & Sons, of Sheffield, England, from whom it has been received in lots as finished. The ingots for the breech-receivers for the 8-inch breech-loading rifles were tempered in oil after hammering, but the manufacturers declined subjecting the corresponding ingots for the 11 and 12 inch rifles to the same process in consequence of their bulk and the irregularity of their shapes. As without this operation of oil tempering, however, the manufacturers would not undertake to reach the standard prescribed for the tempered ingots, specimens were taken from the untempered breech-block (from the same manufacturer) of one of the 8-inch breech-loading rifles, under process of construction at the South Boston foundry, which were tested at the Ordnance Agency, and the physical properties thus determined accepted as a standard for the untempered ingots.

The following results were obtained:

| Specimen. | Length. | Diameter. | Specific gravity. | Tensile strength, per □″ under gradually increasing strains. | Elastic limit. | Extension, per inch, at rupture. | Original area of cross-section. | Area after rupture. | Character of fracture. |
|---|---|---|---|---|---|---|---|---|---|
| Firth's steel taken from breech block for 8-inch breech-loading chambered rifle | *In.* 7.00 | *In.* 0.651 | ...... | *Lbs.* 66,000 | *Lbs.* 21,000 | *In.* 0.2143 | *Sq. in.* 0.333 | 0.189 | Granular and fibrous. |
| Do | 7.00 | 0.652 | ...... | 70,000 | 34,000 | 0.1475 | 0.33378 | 0.27618 | Crystalline. |
| Do | 7.00 | 0.652 | 7.8650 | 82,440 | 23,000 | 0.2031 | 0.3838 | 0.23758 | Fibrous and crystalline. |
| Do | 10.00 | 0.652 | ...... | 62,000 | 20,000 | 0.2175 | 0.3338 | 0.2697 | Light gray metallic luster crystalline. |

At the request of the founders, Messrs. Firth & Sons furnished copies of records of their tests for determining physical properties, as well as a diagram of specimen and explanation of terms used. These are appended to this report.

The specimens tested at the Ordnance Agency were all taken longitudinally from the pieces removed from the breech-receivers to form the slot for the breech-block.

Copies of the records of all specimens tested are herewith attached.

*Results of tests by tensile strain on specimens cut from five 8-inch jackets supplied to Messrs. Paulding, Kemble & Co., West Point foundry, March 30, 1881.*

TESTS FROM JACKETS BEFORE OIL-TEMPERING.

| | | |
|---|---|---|
| **Breaking strain per square inch:** | | |
| S. Soft | tons.. | 32.17 |
| L. Tempered | do... | 46.34$\frac{3}{8}$ |
| H. Tempered | do... | 46.91 |
| **Elongation:** | | |
| S. Soft | inch.. | .55$\frac{1}{8}$ |
| L. Tempered | do... | .39$\frac{1}{8}$ |
| H. Tempered | do... | .38 |

TESTS FROM JACKETS AFTER OIL-TEMPERING.

| | | |
|---|---|---|
| **Breaking strain per square inch:** | | |
| O. H. • | tons.. | 38.76$\frac{3}{8}$ |
| O. H. •• | do... | 43.62$\frac{3}{8}$ |
| O. H. ∴ | do... | 40.72$\frac{1}{8}$ |
| **Elongation:** | | |
| O. H. • | | .22$\frac{1}{8}$ |
| O. H. •• | | .25 |
| O. H. ∴ | | .20$\frac{5}{8}$ |

*Results of tests by tensile strain on specimens cut from five 8-inch slide-bars, supplied to Messrs. Paulding, Kemble & Co., West Point foundry, March 30, 1881.*

TESTS FROM SLIDE-BARS BEFORE OIL-TEMPERING.

| | | |
|---|---|---|
| **Breaking strain per square inch:** | | |
| S. Soft | tons.. | 34.68 |
| L. Tempered | do... | 54.33$\frac{1}{8}$ |
| H. Tempered | do... | 51.97 |
| **Elongation:** | | |
| S. Soft | inch.. | .35$\frac{3}{8}$ |
| L. Tempered | do... | .19 |
| H. Tempered | do... | .19$\frac{3}{8}$ |

TESTS FROM SLIDE-BARS AFTER OIL-TEMPERING.

| | | |
|---|---|---|
| **Breaking strain per square inch:** | | |
| S. Soft | tons.. | 39.77$\frac{3}{8}$ |
| L. Tempered | do... | 40.79 |
| H. Tempered | do... | 40.04$\frac{3}{8}$ |
| **Elongation:** | | |
| S. Soft | inch.. | .23$\frac{3}{8}$ |
| L. Tempered | do... | .17$\frac{3}{8}$ |
| H. Tempered | do... | .25 |

*Results of tests by tensile strain on specimens cut from 11-inch jacket and 11-inch slide-bar, supplied to Messrs. Paulding, Kemble & Co., April 7, 1881.*

TESTS FROM JACKET.

| | | |
|---|---|---|
| Breaking strain per square inch: | | |
| S. Soft | tons.. | 27.90 |
| L. Tempered | do... | 42.07 |
| H. Tempered | do... | 40.72 |
| Elongation: | | |
| S. Soft | inch.. | .55 |
| L. Tempered | do... | .40 |
| H. Tempered | do... | .42 |

TESTS FROM SLIDE-BAR.

| | | |
|---|---|---|
| Breaking strain per square inch: | | |
| S. Soft | tons.. | 32.96 |
| L. Tempered | do... | 51.86 |
| H. Tempered | do... | 54.22 |
| Elongation: | | |
| S. Soft | inch.. | .54 |
| L. Tempered | do... | .16 |
| H. Tempered | do... | .22 |

*Reference to the marks, etc., shown on our test report.*

S. Soft:

Test made from disc cut from forging previous to its being turned or tempered in oil, and tested in the soft state.

L. Tempered:

Test made from disc cut from forging previous to its being turned or tempered in oil, and turned to the size shown on diagram (.658″), then tempered in oil at a *low cherry-red heat*, and afterwards turned to the proper size (.533″) and tested.

H. Tempered:

Same, but tempered in oil at a *high cherry-red heat*, and afterwards turned to the proper size (.533″) and tested.

O. H. Oil tempered:
.. Oil tempered:
.·. Oil tempered:

Tests made from disc cut from forging after it has been rough finished, tempered in oil.

The dots merely denote the number (1, 2, and 3) of specimens tested.

NORFOLK WORKS, *Sheffield*, *June* 2, 1881.

## DIAGRAM OF TESTING PIECE FOR TENSILE STRAIN.

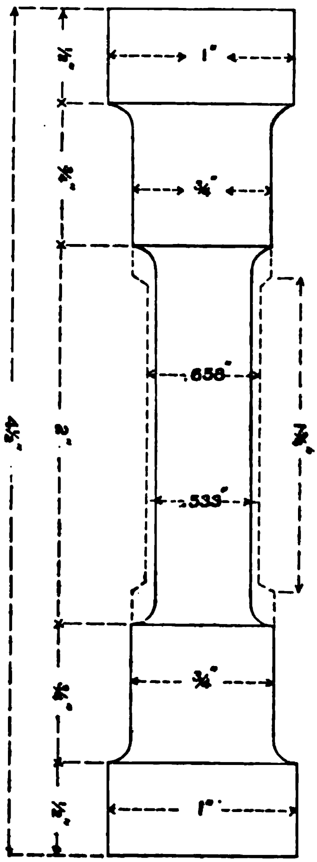
[Full lines show finished sizes. Dotted lines show the amount left on the specimen previously to its being tempered or hardened in oil. The strains are calculated on the primary sections.]

WOOLWICH STANDARD.

FULL SIZE.

| | Tons per square inch at— | | Elongation in a specimen which has the breaking part 2″ long. |
|---|---|---|---|
| | Yielding. | Breaking. | |
| | | | Inch. |
| **Soft:** | | | |
| Low | 11.5 up to 14.0 | 28.5 up to 34.0 | .20 up to .60 |
| High | | | or anything above. |
| **Tempered:** | | | |
| Low | 29.0 up to 34.0 | 40.0 up to 58.0 | .05 up to .30 |
| High | | | or anything above. |

Diameter of testing piece .533″ = area .2231″ .2231″ × 4½ = say 1 square inch.




NORFOLK WORKS, *Sheffield, June* 2, 1881.

TABLE 1.—*Summary of results contained in the following tables.*

| Specimen. | Number of breech-receiver. | Rifle. | Tenacity. | Elastic limit. | Extension per inch. | Specific gravity. | Hardness. | Character of fracture. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | | | *Lbs.* | *Lbs.* | *Inch.* | | | | |
| 1 | 1 | 8-inch | 84,000 | 22,000 | 0.240 | 7.9184 | 17.999 | Fine, fibrous | |
| 2 | 1 | ....do | 84,000 | 49,000 | 0.207 | | | ......do | |
| 1 | 2 | ....do | 82,000 | 34,000 | 0.245 | | | Fibrous, with small crystalline spots | |
| 2 | 2 | ....do | 83,000 | 43,000 | 0.217 | 7.8326 | 18.287 | Fine, fibrous | |
| 1 | 3 | ....do | 85,000 | 48,000 | 0.233 | | | ......do | |
| 2 | 3 | ....do | 86,000 | 47,000 | 0.254 | | | ......do | |
| 1 | 4 | ....do | 85,000 | 45,000 | 0.249 | 7.8818 | 17.999 | Fibrous, with small crystalline spots | Outside of ingot. |
| 2 | 4 | ....do | 80,000 | 43,000 | 0.216 | 7.8233 | 17.535 | Fine, but loosely connected structure, with crystalline spots throughout. | Near bore of ingot. |
| 1 | 5 | ....do | 74,000 | 40,000 | 0.254 | 7.9002 | 14.73 | Fine, fibrous | Specific gravity and hardness, mean of three results, given in Table 3. |
| 2 | 5 | ....do | 74,000 | 40,000 | 0.261 | 7.9002 | 14.73 | ......do | |
| 3 | 5 | ....do | 82,000 | 45,000 | 0.171 | 7.8979 | 18.981 | ......do | 6 inches between shoulders. |
| 4 | 5 | ....do | 78,000 | 47,000 | 0.098 | 7.8586 | 21.169 | Crystalline, radiating from small spot of much finer structure on one side. | Do. |
| 5 | 5 | ....do | 75,000 | 35,000 | 0.270 | 7.9002 | 14.73 | Fine, fibrous, with minute crystalline spots | Specific gravity and hardness from Table 3. |
| 1 | 1 | 11-inch | 61,000 | 22,000 | 0.224 | 7.8775 | 9.813 | Coarse, fibrous, with occasional granular spots | Outside ... These specimens were taken out side by side, but the order of sequence is uncertain beyond the extent indicated. |
| 2 | 1 | ....do | 51,000 | 22,000 | 0.052 | 7.8816 | 9.718 | Granular | |
| 3 | 1 | ....do | 60,000 | 19,000 | 0.290 | 7.8746 | 9.929 | Coarse, fibrous, with granular spots | |
| 4 | 1 | ....do | 60,000 | 19,000 | 0.309 | 7.9215 | 9.313 | Medium gray, mixed fibrous and crystalline | Inside .... |
| 5 | 1 | ....do | 59,000 | 17,000 | 0.284 | 7.8889 | 9.138 | Light gray, crystalline predominating | |
| 1 | 2 | ....do | 62,000 | 19,000 | 0.268 | 7.9088 | 11.594 | Close, fibrous | |
| 2 | 2 | ....do | 62,000 | 22,000 | 0.289 | 7.9672 | 10.601 | ......do | |
| 3 | 2 | ....do | 62,000 | 19,000 | 0.304 | 7.9063 | 9.718 | Fibrous | |
| 1 | 1 | 12-inch | 61,000 | 20,000 | 0.291 | 7.8279 | 13.986 | Medium gray, fibrous, and slightly crystalline | Numbered as they were taken from block, commencing with outside specimen. |
| 2 | 1 | Howitzer | 62,000 | 17,000 | 0.227 | 7.9422 | 12.716 | Mixed, crystalline, and half fibrous | |
| 3 | 1 | ....do | 60,000 | 17,000 | 0.292 | 7.9231 | 15.432 | Medium gray; crystalline predominating | |

TABLE 2.—*Showing the influence of the indentations made in testing for hardness upon the specific gravity of disks.*

| Specimen. | No. of breech-receiver. | Specific gravity before test for hardness. | Specific gravity after test for hardness. | Hardness. | Remarks. |
|---|---|---|---|---|---|
| 1 | 2 | 7.9184 | 7.9396 | 17.999 | From disks cut from ends of specimens which had been previously tested for tensile strength. |
| 2 | 2 | 7.8326 | 7.9315 | 18.287 | |
| 1 | 4 | 7.8818 | 7.9122 | 17.999 | |
| 2 | 4 | 7.8233 | 7.9149 | 17.535 | |

TABLE 3.—*Results of tests for specific gravity and hardness in the case of 8-inch breech-receiver No. 5.*

| Specimen. | Specific gravity of half specimen. | Specific gravity of disk cut from same half specimen after test for hardness. | Hardness. | Remarks. |
|---|---|---|---|---|
| 3 | 7.8979 | 7.8865 | 18.981 | These specimens had been tested for tensile strength. |
| 4 | 7.8586 | 7.9031 | 21.169 | |
| | Specific gravity. | | | |
| 5 | | 7.8587 | 13.98 | These disks were cut from the same block as the foregoing and the specific gravity taken before indentations were made. Inserted in records of specimens 1, 2, and 5, Table 1. |
| 6 | | 7.9600 | 13.98 | |
| 7 | | 7.8818 | 16.23 | |
| | Mean.... | 7.9002 | 14.73 | |

With the exception of specimens 3 and 4 from 8-inch breech-receiver No. 5, which were 6 inches between shoulders (all specimens were 3 inches between shoulders). Except in the cases contained in Tables 2 and 3, the specific gravities were obtained from disks cut from the ends of specimens while being turned, and which were subsequently tested for hardness. The hardness was determined by indentations under a pressure of 10,000 pounds, as practiced by Major Wade.

SPECIMEN I.—*Table showing the extension, restoration, and permanent set per inch in length caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel, three inches long (between shoulders) and 0.623 inch diameter, taken from breech-receiver No. 1 for 8-inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 6,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 7,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 8,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 9,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 10,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 11,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 12,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 13,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |

SPECIMEN I.—*Table showing the extension, restoration, and permanent set, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 14,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 15,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 16,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 17,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 18,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 19,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 20,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 21,000 | .00133 | .00033 | .00133 | .00033 | .00000 | .00000 |
| 22,000 | .00133 | .00000 | .00100 | -.00033 | .00033 | .00033 |
| 23,000 | .00133 | .00000 | .00067 | -.00033 | .00067 | .00034 |
| 24,000 | .00167 | .00034 | .00100 | .00033 | .00067 | .00000 |
| 25,000 | .00167 | .00000 | .00100 | .00000 | .00067 | .00000 |
| 26,000 | .00200 | .00033 | .00133 | .00033 | .00067 | .00000 |
| 27,000 | .00200 | .00000 | .00133 | .00000 | .00067 | .00000 |
| 28,000 | .00200 | .00000 | .00133 | .00000 | .00067 | .00000 |
| 29,000 | .00200 | .00000 | .00100 | -.00033 | .00100 | .00033 |
| 30,000 | .00200 | .00000 | .00100 | .00000 | .00100 | .00033 |
| 31,000 | .00333 | .00133 | .00133 | .00033 | .00200 | .00100 |
| 32,000 | .00367 | .00034 | .00167 | .00034 | .00200 | .00000 |
| 33,000 | .00367 | .00000 | .00167 | .00000 | .00200 | .00000 |
| 34,000 | .00367 | .00000 | .00133 | -.00034 | .00233 | .00033 |
| 35,000 | .00367 | .00000 | .00133 | .00000 | .00233 | .00000 |
| 36,000 | .00400 | .00033 | .00167 | .00034 | .00233 | .00000 |
| 37,000 | .00400 | .00000 | .00167 | .00000 | .00233 | .00000 |
| 38,000 | .00433 | .00033 | .00167 | .00000 | .00267 | .00034 |
| 39,000 | .00467 | .00034 | .00167 | .00000 | .00300 | .00033 |
| 40,000 | .00567 | .00100 | .00200 | .00033 | .00367 | .00067 |
| 41,000 | .00600 | .00033 | .00233 | .00033 | .00367 | .00000 |
| 42,000 | .00667 | .00067 | .00233 | .00000 | .00433 | .00066 |
| 43,000 | .00733 | .00066 | .00233 | .00000 | .00500 | .00067 |
| 44,000 | .00800 | .00067 | .00267 | .00034 | .00533 | .00033 |
| 45,000 | .00867 | .00067 | .00233 | -.00034 | .00633 | .00100 |
| 46,000 | .00900 | .00033 | .00200 | -.00033 | .00700 | .00067 |
| 47,000 | .00967 | .00067 | .00200 | .00000 | .00767 | .00067 |
| 48,000 | .01067 | .00100 | .00233 | .00033 | .00833 | .00066 |
| 49,000 | .01100 | .00033 | .00233 | .00000 | .00867 | .00034 |
| 50,000 | .01233 | .00133 | .00233 | .00000 | .01000 | .00133 |
| 51,000 | .01333 | .00100 | .00267 | .00034 | .01067 | .00067 |
| 52,000 | .01467 | .00134 | .00233 | -.00034 | .01233 | .00166 |
| 53,000 | .01600 | .00133 | .00300 | .00067 | .01300 | .00067 |
| 54,000 | .01767 | .00167 | .00267 | -.00033 | .01500 | .00200 |
| 55,000 | .01867 | .00100 | .00267 | .00000 | .01600 | .00100 |
| 56,000 | .01967 | .00100 | .00267 | .00000 | .01700 | .00100 |
| 57,000 | .02067 | .00100 | .00267 | .00000 | .01800 | .00100 |
| 58,000 | .02200 | .00133 | .00300 | .00033 | .01900 | .00100 |
| 59,000 | .02333 | .00133 | .00333 | .00033 | .02000 | .00100 |
| 60,000 | .02467 | .00134 | .00300 | -.00033 | .02167 | .00167 |
| 61,000 | .02633 | .00166 | .00300 | .00000 | .02333 | .00166 |
| 62,000 | .02800 | .00167 | .00300 | .00000 | .02500 | .00167 |
| 63,000 | .02933 | .00133 | .00333 | .00033 | .02600 | .00100 |
| 64,000 | .03033 | .00100 | .00333 | .00000 | .02700 | .00100 |
| 65,000 | .03233 | .00200 | .00333 | .00000 | .02900 | .00200 |
| 66,000 | .03500 | .00267 | .00367 | .00034 | .03133 | .00233 |
| 67,000 | .03733 | .00233 | .00367 | .00000 | .03367 | .00234 |
| 68,000 | .03933 | .00200 | .00400 | .00033 | .03533 | .00166 |
| 69,000 | .04133 | .00200 | .00400 | .00000 | .03733 | .00200 |
| 70,000 | .04367 | .00234 | .00367 | -.00033 | .04000 | .00267 |
| 71,000 | .04567 | .00200 | .00367 | .00000 | .04200 | .00200 |
| 72,000 | .04900 | .00333 | .00400 | .00033 | .04500 | .00300 |
| 73,000 | .05133 | .00233 | .00400 | .00000 | .04733 | .00233 |
| 74,000 | .05567 | .00434 | .00433 | .00033 | .05133 | .00400 |
| 75,000 | .06033 | .00466 | .00433 | .00000 | .05600 | .00467 |
| 76,000 | .06433 | .00400 | .00433 | .00000 | .06000 | .00400 |
| 77,000 | .06833 | .00400 | .00433 | .00000 | .06400 | .00400 |
| 78,000 | .07500 | .00667 | .00500 | .00067 | .07000 | .00600 |
| 79,000 | .08433 | .00933 | .00633 | .00133 | .07800 | .00800 |
| 80,000 | .09000 | .00567 | .00467 | -.00166 | .08533 | .00733 |
| 81,000 | .10167 | .01167 | .00467 | .00000 | .09700 | .01167 |
| 82,000 | .11767 | .01600 | .00733 | .00266 | .11033 | .01333 |
| 83,000 | .14833 | .03066 | 0.00667 | -0.00066 | 0.14167 | 0.03134 |
| 84,000 | 0.24033 | 0.09200 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | | | |
|---|---|---|---|
| Specific gravity | 7.9184 | Hardness | 17.999 |
| Tensile strength per square inch ....lbs.. | 84,000 | Original area of cross-section..sq. inch.. | 0.3048 |
| Elastic limit.....lbs.. | 22,000 | Area after rupture ......sq. inch.. | 0.1705 |
| Extension per inch at elastic limit .inch.. | 0.00133 | Position of rupture .......... | ⅜ from shoulder. |
| Extension per inch at rupture......inch.. | 0.24033 | Character of fracture.......... | Fine, fibrous. |

SPECIMEN II.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel, 3 inches long (between shoulders) and 0.624 inch diameter, taken from breech-receiver No. 1 for 8-inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 9,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 10,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 11,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 12,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 13,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 14,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 15,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 16,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 17,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 18,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 19,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 20,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 21,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 22,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 23,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 24,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 25,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 26,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 27,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 28,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 29,000 | .00133 | .00033 | .00133 | .00033 | .00000 | .00000 |
| 30,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 31,000 | .00167 | .00034 | .00167 | .00034 | .00000 | .00000 |
| 32,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 33,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 34,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 35,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 36,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 37,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 38,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 39,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 40,000 | .00200 | .00033 | .00200 | .00033 | .00000 | .00000 |
| 41,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 42,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 43,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 44,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 45,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 46,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 47,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 48,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 49,000 | .00300 | .00100 | .00167 | —.00033 | .00133 | .00133 |
| 50,000 | .00500 | .00200 | .00200 | .00033 | .00300 | .00167 |
| 51,000 | .01167 | .00667 | .00267 | .00067 | .00900 | .00600 |
| 52,000 | .01333 | .00166 | .00267 | .00000 | .01067 | .00167 |
| 53,000 | .01467 | .00134 | .00300 | .00033 | .01167 | .00100 |
| 54,000 | .01567 | .00100 | .00300 | .00000 | .01237 | .00100 |
| 55,000 | .01733 | .00166 | .00300 | .00000 | .01433 | .00166 |
| 56,000 | .01800 | .00067 | .00300 | .00000 | .01500 | .00067 |

SPECIMEN II.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 57, 000 | 0. 01833 | 0. 00033 | 0. 00300 | 0. 00000 | 0. 01533 | 0. 00033 |
| 58, 000 | . 01900 | . 00067 | . 00267 | —. 00033 | . 01633 | . 00100 |
| 59, 000 | . 01967 | . 00067 | . 00300 | . 00033 | . 01667 | . 00034 |
| 60, 000 | . 02067 | . 00100 | . 00300 | . 00000 | . 01767 | . 00100 |
| 61, 000 | | | | | | |
| 62, 000 | . 02367 | | . 00367 | | . 02000 | |
| 63, 000 | . 02600 | . 00233 | . 00367 | . 00000 | . 02233 | . 00233 |
| 64, 000 | . 02700 | . 00100 | . 00333 | —. 00034 | . 02367 | . 00134 |
| 65, 000 | . 02833 | . 00133 | . 00400 | . 00067 | . 02433 | . 00066 |
| 66, 000 | . 03033 | . 00200 | . 00433 | . 00033 | . 02600 | . 00167 |
| 67, 000 | . 03233 | . 00200 | . 00367 | —. 00066 | . 02867 | . 00267 |
| 68, 000 | . 03400 | . 00167 | . 00400 | . 00033 | . 03000 | . 00133 |
| 69, 000 | . 03533 | . 00133 | . 00400 | . 00000 | . 03133 | . 00133 |
| 70, 000 | . 03867 | . 00334 | . 00400 | . 00000 | . 03467 | . 00334 |
| 71, 000 | . 04100 | . 00233 | . 00433 | . 00033 | . 03667 | . 00200 |
| 72, 000 | . 04700 | . 00600 | . 00433 | . 00000 | . 04267 | . 00600 |
| 73, 000 | . 04833 | . 00133 | . 00433 | . 00000 | . 04400 | . 00133 |
| 74, 000 | . 05067 | . 00234 | . 00467 | . 00034 | . 04600 | . 00200 |
| 75, 000 | . 05267 | . 00200 | . 00467 | . 00000 | . 04800 | . 00200 |
| 76, 000 | . 06200 | . 00933 | . 00533 | . 00066 | . 05667 | . 00867 |
| 77, 000 | . 06367 | . 00167 | . 00567 | . 00034 | . 05800 | . 00133 |
| 78, 000 | . 06733 | . 00367 | . 00567 | . 00000 | . 06167 | . 00367 |
| 79, 000 | . 07300 | . 00567 | . 00467 | —. 00100 | . 06833 | . 00666 |
| 80, 000 | . 07967 | . 00667 | . 00533 | . 00066 | . 07433 | . 00600 |
| 81, 000 | . 08867 | . 00900 | . 00500 | —. 00033 | . 08367 | . 00934 |
| 82, 000 | . 09600 | . 00733 | . 00500 | . 00000 | . 09100 | . 00733 |
| 83, 000 | . 11533 | . 01933 | 0. 00533 | 0. 00033 | 0. 11000 | 0. 01900 |
| 84, 000 | 0. 20733 | 0. 09200 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

Specific gravity ........................................
Tensile strength, per square inch ........................ pounds.. 84, 000
Elastic limit ........................................ pounds.. 49, 000
Extension per inch at elastic limit ........................ inch.. 0, 00300
Extension per inch at rupture ........................ inch.. 0. 20733
Hardness ........................................
Original area of cross-section ........................ square inch.. 0. 3056
Area after rupture ........................ square inch.. 0. 1506
Position of rupture ........................ ⅓ from shoulder.
Character of fracture ........................ Fine fibrous.

SPECIMEN I.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel* 3 *inches long* (*between shoulders*) *and* 0.623 *inches diameter, taken from breech-receiver No.* 2, *for* 8-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00033 | . 00033 | . 00033 | . 00033 | . 00000 | . 00000 |
| 4, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 5, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |

SPECIMEN I.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 6,000 | 0.00033 | 0.00000 | 0.00033 | 0.00000 | 0.00000 | 0.00000 |
| 7,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 8,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 9,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 10,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 11,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 12,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 13,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 14,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 15,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 16,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 17,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 18,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 19,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 20,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 21,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 22,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 23,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 24,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 25,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 26,000 | .00133 | .00033 | .00133 | .00033 | .00000 | .00000 |
| 27,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 28,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 29,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 30,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 31,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 32,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 33,000 | .00167 | .00034 | .00167 | .00034 | .00000 | .00000 |
| 34,000 | .00200 | .00033 | .00133 | —.00034 | .00067 | .00067 |
| 35,000 | .00267 | .00067 | .00167 | .00034 | .00100 | .00033 |
| 36,000 | .00300 | .00033 | .00200 | .00033 | .00100 | .00000 |
| 37,000 | .00333 | .00033 | .00167 | —.00033 | .00167 | .00067 |
| 38,000 | .00500 | .00167 | .00167 | .00000 | .00333 | .00166 |
| 39,000 | .00600 | .00100 | .00233 | .00066 | .00367 | .00034 |
| 40,000 | .00600 | .00000 | .00200 | —.00033 | .00400 | .00033 |
| 41,000 | .00600 | .00000 | .00200 | .00000 | .00400 | .00000 |
| 42,000 | .00667 | .00067 | .00200 | .00000 | .00467 | .00067 |
| 43,000 | .00767 | .00100 | .00267 | .00067 | .00500 | .00033 |
| 44,000 | .00800 | .00033 | .00200 | —.00067 | .00600 | .00100 |
| 45,000 | .01000 | .00200 | .00233 | .00033 | .00767 | .00167 |
| 46,000 | .01067 | .00067 | .00233 | .00000 | .00833 | .00066 |
| 47,000 | .01133 | .00066 | .00267 | .00034 | .00867 | .00034 |
| 48,000 | .01200 | .00067 | .00267 | .00000 | .00933 | .00066 |
| 49,000 | .01267 | .00067 | .00267 | .00000 | .01000 | .00067 |
| 50,000 | .01333 | .00066 | .00267 | .00000 | .01067 | .00067 |
| 51,000 | .01433 | .00100 | .00267 | .00000 | .01167 | .00100 |
| 52,000 | .01567 | .00134 | .00267 | .00000 | .01300 | .00133 |
| 53,000 | .01667 | .00100 | .00267 | .00000 | .01400 | .00100 |
| 54,000 | .01767 | .00100 | .00300 | .00033 | .01467 | .00067 |
| 55,000 | .01933 | .00166 | .00300 | .00000 | .01633 | .00166 |
| 56,000 | .02067 | .00134 | .00300 | .00000 | .01767 | .00134 |
| 57,000 | .02133 | .00066 | .00300 | .00000 | .01833 | .00066 |
| 58,000 | .02300 | .00167 | .00333 | .00033 | .01967 | .00134 |
| 59,000 | .02467 | .00167 | .00333 | .00000 | .02133 | .00166 |
| 60,000 | .02600 | .00133 | .00367 | .00034 | .02233 | .00100 |
| 61,000 | .02967 | .00367 | .00300 | —.00067 | .02667 | .00434 |
| 62,000 | .03133 | .00166 | .00333 | .00033 | .02800 | .00133 |
| 63,000 | .03267 | .00134 | .00367 | .00034 | .02900 | .00100 |
| 64,000 | .03333 | .00066 | .00367 | .00000 | .02967 | .00067 |
| 65,000 | .03567 | .00234 | .00367 | .00000 | .03200 | .00233 |
| 66,000 | .03800 | .00233 | .00367 | .00000 | .03433 | .00233 |
| 67,000 | .04100 | .00300 | .00400 | .00033 | .03700 | .00267 |
| 68,000 | .04367 | .00267 | .00433 | .00033 | .03933 | .00233 |
| 69,000 | .04633 | .00266 | .00433 | .00000 | .04200 | .00267 |
| 70,000 | .04867 | .00234 | .00400 | —.00033 | .04467 | .00267 |
| 71,000 | .05133 | .00266 | .00467 | .00067 | .04667 | .00200 |
| 72,000 | .05533 | .00400 | .00433 | —.00034 | .05100 | .00433 |
| 73,000 | .05933 | .00400 | .00467 | .00034 | .05467 | .00367 |
| 74,000 | .06467 | .00534 | .00433 | —.00034 | .06033 | .00566 |
| 75,000 | .07000 | .00533 | .00433 | .00000 | .06567 | .00534 |
| 76,000 | .07633 | .00633 | .00500 | .00067 | .07133 | .00566 |
| 77,000 | .08400 | .00767 | .00467 | —.00033 | .07600 | .00467 |
| 78,000 | .09433 | .01033 | .00467 | .00000 | .08967 | .01367 |

SPECIMEN I.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 79, 000 | 0. 10467 | 0. 01034 | 0. 00500 | 0. 00033 | 0. 09967 | 0. 01000 |
| 80, 000 | . 12367 | . 01900 | . 00633 | . 00133 | . 11733 | . 01766 |
| 81, 000 | . 15400 | . 03033 | 0. 00533 | —0. 00100 | 0. 14867 | 0. 03134 |
| 82, 000 | 0. 24533 | 0. 09133 | (*) | (*) | (*) | (*) |

* Specimen broke.

GENERAL SUMMARY.

| | | |
|---|---|---|
| Specific gravity | | |
| Tensile strength, per square inch | pounds.. | 82, 000 |
| Elastic limit | pounds.. | 34, 000 |
| Extension, per inch, at elastic limit | inch.. | 0. 00200 |
| Extension, per inch, at rupture | inch.. | 0. 24533 |
| Hardness | | |
| Original area of cross-section | square inch.. | 0. 3048 |
| Area after rupture | square inch.. | 0. 1534 |
| Position of rupture | | ½ from shoulder. |
| Character of fracture | | fibrous, slightly crystallized. |

SPECIMEN II.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel* 3 *inches long (between shoulders) and* 0.624 *inches diameter, taken from breech-receiver No.* 2, *for* 8 *inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 4, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 5, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 6, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 7, 000 | . 00033 | . 00033 | . 00033 | . 00033 | . 00000 | . 00000 |
| 8, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 9, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 10, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 11, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 12, 000 | . 00067 | . 00034 | . 00067 | . 00034 | . 00000 | . 00000 |
| 13, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 14, 000 | . 00100 | . 00033 | . 00100 | . 00033 | . 00000 | . 00000 |
| 15, 000 | . 00133 | . 00033 | . 00133 | . 00033 | . 00000 | . 00000 |
| 16, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 17, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 18, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 19, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 20, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 21, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 22, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 23, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 24, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 25, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 26, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 27, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 28, 000 | . 00167 | . 00034 | . 00167 | . 00034 | . 00000 | . 00000 |
| 29, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 30, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |

SPECIMEN I.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 31, 000 | 0. 00167 | 0. 00000 | 0. 00167 | 0. 00000 | 0. 00000 | 0. 00000 |
| 32, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 33, 000 | . 00200 | . 00033 | . 00200 | . 00033 | . 00000 | . 00000 |
| 34, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 35, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 36, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 37, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 38, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 39, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 40, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 41, 000 | . 00233 | . 00033 | . 00233 | . 00033 | . 00000 | . 00000 |
| 42, 000 | . 00233 | . 00000 | . 00233 | . 00000 | . 00000 | . 00000 |
| 43, 000 | . 00233 | . 00000 | . 00200 | —. 00033 | . 00033 | . 00033 |
| 44, 000 | . 00233 | . 00000 | . 00200 | . 00000 | . 00033 | . 00000 |
| 45, 000 | . 00233 | . 00000 | . 00167 | —. 00033 | . 00067 | . 00034 |
| 46, 000 | . 00367 | . 00134 | . 002 | . 00033 | . 00167 | . 00100 |
| 47, 000 | . 00600 | . 00233 | . 00133 | —. 00067 | . 00467 | . 00300 |
| 48, 000 | . 00833 | . 00233 | . 00200 | . 00067 | . 00633 | . 00166 |
| 49, 000 | . 01000 | . 00167 | . 00167 | —. 00033 | . 00833 | . 00200 |
| 50, 000 | . 01333 | . 00333 | . 00200 | . 00033 | . 01133 | . 00300 |
| 51, 000 | . 01467 | . 00134 | . 00267 | . 00067 | . 01200 | . 00067 |
| 52, 000 | . 01567 | . 00100 | . 00267 | . 00000 | . 01300 | . 00100 |
| 53, 000 | . 01700 | . 00133 | . 00300 | . 00033 | . 01400 | . 00100 |
| 54, 000 | . 01800 | . 00100 | . 00233 | —. 00067 | . 01567 | . 00167 |
| 55, 000 | . 01933 | . 00133 | . 00300 | . 00067 | . 01633 | . 00066 |
| 56, 000 | . 02033 | . 00100 | . 00300 | . 00000 | . 01733 | . 00100 |
| 57, 000 | . 02200 | . 00167 | . 00300 | . 00000 | . 01900 | . 00167 |
| 58, 000 | . 02300 | . 00100 | . 00333 | . 00033 | . 01967 | . 00067 |
| 59, 000 | . 02400 | . 00100 | . 00300 | —. 00033 | . 02100 | . 00133 |
| 60, 000 | . 02567 | . 00167 | . 00300 | . 00000 | . 02267 | . 00167 |
| 61, 000 | . 02700 | . 00133 | . 00333 | . 00033 | . 02367 | . 00100 |
| 62, 000 | . 02800 | . 00100 | . 00300 | —. 00033 | . 02500 | . 00133 |
| 63, 000 | . 03000 | . 00200 | . 00333 | . 00033 | . 02667 | . 00167 |
| 64, 000 | . 03167 | . 00167 | . 00333 | . 00000 | . 02833 | . 00166 |
| 65, 000 | . 03400 | . 00233 | . 00333 | . 00000 | . 03067 | . 00234 |
| 66, 000 | . 03567 | . 00167 | . 00333 | . 00000 | . 03233 | . 00166 |
| 67, 000 | . 03833 | . 00266 | . 00333 | . 00000 | . 03500 | . 00267 |
| 68, 000 | . 04100 | . 00267 | . 00367 | . 00034 | . 03733 | . 00233 |
| 69, 000 | . 04400 | . 00300 | . 00367 | . 00000 | . 04033 | . 00300 |
| 70, 000 | . 04667 | . 00267 | . 00367 | . 00000 | . 04300 | . 00267 |
| 71, 000 | . 04967 | . 00300 | . 00400 | . 00033 | . 04567 | . 00267 |
| 72, 000 | . 05300 | . 00333 | . 00433 | . 00033 | . 04867 | . 00300 |
| 73, 000 | . 05600 | . 00300 | . 00400 | —. 00033 | . 05200 | . 00333 |
| 74, 000 | . 06000 | . 00400 | . 00400 | . 00000 | . 05600 | . 00400 |
| 75, 000 | . 06433 | . 00433 | . 00433 | . 00033 | . 06000 | . 00400 |
| 76, 000 | . 06900 | . 00467 | . 00433 | . 00000 | . 06467 | . 00467 |
| 77, 000 | . 07433 | . 00533 | . 00500 | . 00067 | . 06933 | . 00466 |
| 78, 000 | . 08133 | . 00700 | . 00467 | —. 00033 | . 07667 | . 00734 |
| 79, 000 | . 08833 | . 00700 | . 00467 | . 00000 | . 08367 | . 00700 |
| 80, 000 | . 09867 | . 01034 | . 00467 | . 00000 | . 09400 | . 01033 |
| 81, 000 | . 11200 | . 01333 | . 00500 | . 00033 | . 10700 | . 01300 |
| 82, 000 | . 13133 | . 01933 | 0. 00500 | 0. 00000 | 0. 12633 | 0. 01933 |
| 83 000 | 0. 21700 | 0. 08567 | (*) | (*) | (*) | ( ) |

* Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7. 8326 |
| Tensile strength, per square inch ... pounds.. | 83, 000 |
| Elastic limit ... pounds.. | 43, 000 |
| Extension, per inch, at elastic limit ... inch.. | 0. 00233 |
| Extension, per inch, at rupture ... inch.. | 0. 21700 |
| Hardness | 18. 287 |
| Original area of cross-section ... square inch.. | 0. 3058 |
| Area after rupture ... square inch.. | 0. 1604 |
| Position of rupture | [illegible] from shoulder. |
| Character of fracture | fine fibrous. |

SPECIMEN I.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 79,000 | 0.10467 | 0.01034 | 0.00500 | 0.00033 | 0.09967 | 0.01000 |
| 80,000 | .12367 | .01900 | .00633 | .00133 | .11733 | .01766 |
| 81,000 | .15400 | .03033 | 0.00533 | —0.00100 | 0.14867 | 0.03134 |
| 82,000 | 0.24533 | 0.09133 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

Specific gravity ..........
Tensile strength, per square inch .......... pounds .. 82,000
Elastic limit .......... pounds .. 34,000
Extension, per inch, at elastic limit .......... inch .. 0.00300
Extension, per inch, at rupture .......... inch .. 0.24533
Hardness ..........
Original area of cross-section .......... square inch .. 0.3048
Area after rupture .......... square inch .. 0.1534
Position of rupture .......... ½ from shoulder.
Character of fracture .......... fibrous, slightly crystallized.

SPECIMEN II.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel* 3 *inches long (between shoulders) and* 0.624 *inches diameter, taken from breech-receiver No.* 2, *for* 8 *inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 8,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 9,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 10,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 11,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 12,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 13,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 14,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 15,000 | .00133 | .00033 | .00133 | .00033 | .00000 | .00000 |
| 16,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 17,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 18,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 19,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 20,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 21,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 22,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 23,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 24,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 25,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 26,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 27,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 28,000 | .00167 | .00034 | .00167 | .00034 | .00000 | .00000 |
| 29,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 30,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |

SPECIMEN I.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 31, 000 | 0. 00167 | 0. 00000 | 0. 00167 | 0. 00000 | 0. 00000 | 0. 00000 |
| 32, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 33, 000 | . 00200 | . 00033 | . 00200 | . 00033 | . 00000 | . 00000 |
| 34, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 35, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 36, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 37, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 38, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 39, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 40, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 41, 000 | . 00233 | . 00033 | . 00233 | . 00033 | . 00000 | . 00000 |
| 42, 000 | . 00233 | . 00000 | . 00233 | . 00000 | . 00000 | . 00000 |
| 43, 000 | . 00233 | . 00000 | . 00200 | — . 00033 | . 00033 | . 00033 |
| 44, 000 | . 00233 | . 00000 | . 00200 | . 00000 | . 00033 | . 00000 |
| 45, 000 | . 00233 | . 00000 | . 00167 | — . 00038 | . 00067 | . 00034 |
| 46, 000 | . 00367 | . 00134 | . 002 | . 00033 | . 00167 | . 00100 |
| 47, 000 | . 00600 | . 00233 | . 00133 | — . 00067 | . 00467 | . 00300 |
| 48, 000 | . 00833 | . 00233 | . 00200 | . 00067 | . 00633 | . 00166 |
| 49, 000 | . 01000 | . 00167 | . 00167 | — . 00033 | . 00833 | . 00200 |
| 50, 000 | . 01333 | . 00333 | . 00200 | . 00033 | . 01133 | . 00300 |
| 51, 000 | . 01467 | . 00134 | . 00267 | . 00067 | . 01200 | . 00067 |
| 52, 000 | . 01567 | . 00100 | . 00267 | . 00000 | . 01300 | . 00100 |
| 53, 000 | . 01700 | . 00133 | . 00300 | . 00033 | . 01400 | . 00100 |
| 54, 000 | . 01800 | . 00100 | . 00233 | — . 00067 | . 01567 | . 00167 |
| 55, 000 | . 01933 | . 00133 | . 00300 | . 00067 | . 01633 | . 00066 |
| 56, 000 | . 02033 | . 00100 | . 00300 | . 00000 | . 01733 | . 00100 |
| 57, 000 | . 02200 | . 00167 | . 00300 | . 00000 | . 01900 | . 00167 |
| 58, 000 | . 02300 | . 00100 | . 00333 | . 00033 | . 01967 | . 00067 |
| 59, 000 | . 02400 | . 00100 | . 00300 | — . 00033 | . 02100 | . 00133 |
| 60, 000 | . 02567 | . 00167 | . 00300 | . 00000 | . 02267 | . 00167 |
| 61, 000 | . 02700 | . 00133 | . 00333 | . 00033 | . 02367 | . 00100 |
| 62, 000 | . 02800 | . 00100 | . 00300 | — . 00033 | . 02500 | . 00133 |
| 63, 000 | . 03000 | . 00200 | . 00333 | . 00033 | . 02667 | . 00167 |
| 64, 000 | . 03167 | . 00167 | . 00338 | . 00000 | . 02833 | . 00166 |
| 65, 000 | . 03400 | . 00233 | . 00333 | . 00000 | . 03067 | . 00234 |
| 66, 000 | . 03567 | . 00167 | . 00333 | . 00000 | . 03233 | . 00166 |
| 67, 000 | . 03833 | . 00266 | . 00333 | . 00000 | . 03500 | . 00267 |
| 68, 000 | . 04100 | . 00267 | . 00367 | . 00034 | . 03733 | . 00233 |
| 69, 000 | . 04400 | . 00300 | . 00367 | . 00000 | . 04033 | . 00300 |
| 70, 000 | . 04667 | . 00267 | . 00367 | . 00000 | . 04300 | . 00267 |
| 71, 000 | . 04967 | . 00300 | . 00400 | . 00033 | . 04567 | . 00267 |
| 72, 000 | . 05300 | . 00333 | . 00433 | . 00033 | . 04867 | . 00300 |
| 73, 000 | . 05600 | . 00300 | . 00400 | — . 00033 | . 05200 | . 00333 |
| 74, 000 | . 06000 | . 00400 | . 00400 | . 00000 | . 05600 | . 00400 |
| 75, 000 | . 06433 | . 00433 | . 00433 | . 00033 | . 06000 | . 00400 |
| 76, 000 | . 06900 | . 00467 | . 00433 | . 00000 | . 06467 | . 00467 |
| 77, 000 | . 07433 | . 00533 | . 00500 | . 00067 | . 06933 | . 00466 |
| 78, 000 | . 08133 | . 00700 | . 00467 | — . 00033 | . 07667 | . 00734 |
| 79, 000 | . 08833 | . 00700 | . 00467 | . 00000 | . 08367 | . 00700 |
| 80, 000 | . 09867 | . 01034 | . 00467 | . 00000 | . 09400 | . 01033 |
| 81, 000 | . 11200 | . 01333 | . 00500 | . 00033 | . 10700 | . 01300 |
| 82, 000 | . 13133 | . 01933 | 0. 00500 | 0. 00000 | 0. 12633 | 0. 01933 |
| 83 000 | 0. 21700 | 0. 08567 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7. 8326 |
| Tensile strength, per square inch ........ pounds.. | 83, 000 |
| Elastic limit ........ pounds.. | 43, 000 |
| Extension, per inch, at elastic limit ........ inch.. | 0. 00233 |
| Extension, per inch, at rupture ........ inch.. | 0. 21700 |
| Hardness | 18. 287 |
| Original area of cross-section ........ square inch.. | 0. 3058 |
| Area after rupture ........ square inch.. | 0. 1604 |
| Position of rupture | ¾ from shoulder. |
| Character of fracture | fine fibrous. |

SPECIMEN I.—*Table showing the extension, restoration, and permanent set, per inch in length caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel 3 inches long (between shoulders) and 0.622 inch diameter, taken from breech-receiver No. 3, for 8-inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 9,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 10,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 11,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 12,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 13,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 15,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 16,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 17,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 18,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 19,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 20,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 21,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 22,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 23,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 24,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 25,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 26,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 27,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 28,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 29,000 | .00133 | .00033 | .00133 | .00033 | .00000 | .00000 |
| 30,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 31,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 32,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 33,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 34,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 35,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 36,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 37,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 38,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 39,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 40,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 41,000 | .00167 | .00034 | .00167 | .00034 | .00000 | .00000 |
| 42,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 43,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 44,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 45,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 46,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 47,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 48,000 | .00267 | .00100 | .00200 | .00033 | .00067 | .00067 |
| 49,000 | .00433 | .00166 | .00200 | .00000 | .00233 | .00166 |
| 50,000 | .00633 | .00200 | .00167 | —.00033 | .00467 | .00234 |
| 51,000 | .01333 | .00700 | .00233 | .00066 | .01100 | .00633 |
| 52,000 | .01467 | .00134 | .00267 | .00034 | .01200 | .00100 |
| 53,000 | .01533 | .00066 | .00267 | .00000 | .01267 | .00067 |
| 54,000 | .01667 | .00134 | .00300 | .00033 | .01367 | .00100 |
| 55,000 | .01733 | .00066 | .00300 | .00000 | .01433 | .00066 |
| 56,000 | .01800 | .00067 | .00267 | —.00033 | .01533 | .00100 |
| 57,000 | .01900 | .00100 | .00267 | .00000 | .01633 | .00100 |
| 58,000 | .02067 | .00167 | .00300 | .00033 | .01767 | .00134 |
| 59,000 | .02233 | .00166 | .00300 | .00000 | .01933 | .00166 |
| 60,000 | .02367 | .00134 | .00300 | .00000 | .02067 | .00134 |
| 61,000 | .02567 | .00200 | .00367 | .00067 | .02200 | .00133 |
| 62,000 | .02767 | .00200 | .00267 | —.00100 | .02500 | .00300 |
| 63,000 | .02900 | .00133 | .00300 | .00033 | .02600 | .00100 |
| 64,000 | .03067 | .00167 | .00333 | .00033 | .02733 | .00133 |
| 65,000 | .03167 | .00100 | .00333 | .00000 | .02833 | .00100 |
| 66,000 | .03333 | .00166 | .00333 | .00000 | .03000 | .00167 |
| 67,000 | 0.03567 | 0.00234 | 0.00400 | 0.00067 | 0.03167 | 0.00167 |

SPECIMEN I.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 68, 000 | 0. 03800 | 0. 00233 | 0. 00333 | —0. 00067 | 0. 03467 | 0. 00300 |
| 69, 000 | . 04033 | . 00233 | . 00333 | . 00000 | . 03700 | . 00233 |
| 70, 000 | . 04333 | . 00300 | . 00400 | . 00067 | . 03933 | . 00233 |
| 71, 000 | . 04600 | . 00267 | . 00433 | . 00033 | . 04167 | . 00234 |
| 72, 000 | . 04833 | . 00233 | . 00333 | — . 00100 | . 04500 | . 00333 |
| 73, 000 | . 05167 | . 00334 | . 00300 | — . 00033 | . 04867 | . 00367 |
| 74, 000 | . 05467 | . 00300 | . 00400 | . 00100 | . 05067 | . 00200 |
| 75, 000 | . 05867 | . 00400 | . 00400 | . 00000 | . 05467 | . 00400 |
| 76, 000 | . 06233 | . 00366 | . 00367 | — . 00033 | . 05867 | . 00400 |
| 77, 000 | . 06667 | . 00434 | . 00433 | . 00066 | . 06233 | . 00366 |
| 78, 000 | . 07367 | . 00700 | . 00400 | — . 00033 | . 06967 | . 00734 |
| 79, 000 | . 07900 | . 00533 | . 00567 | . 00167 | . 07333 | . 00366 |
| 80, 000 | . 08600 | . 00700 | . 00433 | — . 00134 | . 08167 | . 00834 |
| 81, 000 | . 09333 | . 00733 | . 00500 | . 00067 | . 08833 | . 00666 |
| 82, 000 | . 10633 | . 01300 | . 00500 | . 00000 | . 10133 | . 01300 |
| 83, 000 | . 11967 | . 01334 | . 00500 | . 00000 | . 11467 | . 01334 |
| 84, 000 | . 15700 | . 03733 | 0. 02333 | 0. 01833 | 0. 13367 | 0. 01900 |
| 85, 000 | 0. 23333 | 0. 07633 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | |
| Tensile strength, per square inch........pounds.. | 85, 000 |
| Elastic limit........pounds.. | 48, 000 |
| Extension, per inch, at elastic limit........inch.. | 0. 00267 |
| Extension, per inch, at rupture........inch.. | 0. 23333 |
| Hardness | |
| Original area of cross-section........square inch.. | 0. 3038 |
| Area after rupture........square inch.. | 0. 1513 |
| Position of rupture........ | about middle. |
| Character of fracture........ | fine fibrous. |

SPECIMEN II.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel* 3 *inches long (between shoulders) and* 0.622 *inch diameter, taken from breech-receiver No.* 3, *for* 8-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 4, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 5, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 6, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 7, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 8, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 9, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 10, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 11, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 12, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 13, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 14, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 15, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |

SPECIMEN II.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 16, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 17, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 18, 000 | . 00100 | . 00100 | . 00100 | . 00100 | . 00000 | . 00000 |
| 19, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 20, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 21, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 22, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 23, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 24, 000 | . 00133 | . 00033 | . 00133 | . 00033 | . 00000 | . 00000 |
| 25, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 26, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 27, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 28, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 29, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 30, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 31, 000 | . 00167 | . 00034 | . 00167 | . 00034 | . 00000 | . 00000 |
| 32, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 33, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 34, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 35, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 36, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 37, 000 | . 00200 | . 00033 | . 00200 | . 00033 | . 00000 | . 00000 |
| 38, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 39, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 40, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 41, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 42, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 43, 000 | . 00233 | . 00033 | . 00233 | . 00033 | . 00000 | . 00000 |
| 44, 000 | . 00233 | . 00000 | . 00233 | . 00000 | . 00000 | . 00000 |
| 45, 000 | . 00233 | . 00000 | . 00233 | . 00000 | . 00000 | . 00000 |
| 46, 000 | . 00233 | . 00000 | . 00233 | . 00000 | . 00000 | . 00000 |
| 47, 000 | . 00333 | . 00100 | . 00233 | . 00000 | . 00100 | . 00100 |
| 48, 000 | . 00500 | . 00167 | . 00233 | . 00000 | . 00267 | . 00167 |
| 49, 000 | . 00767 | . 00267 | . 00333 | . 00100 | . 00433 | . 00166 |
| 50, 000 | . 00900 | . 00133 | . 00233 | —. 00100 | . 00667 | . 00234 |
| 51, 000 | . 01200 | . 00300 | . 00233 | . 00000 | . 00967 | . 00300 |
| 52, 000 | . 01467 | . 00267 | . 00267 | . 00034 | . 01200 | . 00233 |
| 53, 000 | . 01600 | . 00133 | . 00267 | . 00000 | . 01333 | . 00133 |
| 54, 000 | . 01733 | . 00133 | . 00300 | . 00033 | . 01433 | . 00100 |
| 55, 000 | . 01867 | . 00134 | . 00300 | . 00000 | . 01567 | . 00134 |
| 56, 000 | . 01967 | . 00100 | . 00300 | . 00000 | . 01667 | . 00100 |
| 57, 000 | . 02067 | . 00100 | . 00333 | . 00033 | . 01733 | . 00066 |
| 58, 000 | . 02133 | . 00066 | . 00300 | —. 00033 | . 01833 | . 00100 |
| 59, 000 | . 02267 | . 00134 | . 00333 | . 00033 | . 01933 | . 00100 |
| 60, 000 | . 02367 | . 00100 | . 00300 | —. 00033 | . 02067 | . 00134 |
| 61, 000 | . 02533 | . 00167 | . 00333 | . 00033 | . 02200 | . 00133 |
| 62, 000 | . 02667 | . 00134 | . 00333 | . 00000 | . 02333 | . 00133 |
| 63, 000 | . 02767 | . 00100 | . 00333 | . 00000 | . 02433 | . 00100 |
| 64, 000 | . 02933 | . 00166 | . 00333 | . 00000 | . 02600 | . 00167 |
| 65, 000 | . 03067 | . 00134 | . 00333 | . 00000 | . 02733 | . 00133 |
| 66, 000 | . 03267 | . 00200 | . 00333 | . 00000 | . 02933 | . 00200 |
| 67, 000 | . 03433 | . 00166 | . 00367 | . 00034 | . 03067 | . 00134 |
| 68, 000 | . 03733 | . 00300 | . 00367 | . 00000 | . 03367 | . 00300 |
| 69, 000 | . 03900 | . 00167 | . 00400 | . 00033 | . 03500 | . 00133 |
| 70, 000 | . 04200 | . 00300 | . 00400 | . 00000 | . 03800 | . 00300 |
| 71, 000 | . 04367 | . 00167 | . 00367 | —. 00033 | . 04000 | . 00200 |
| 72, 000 | . 04633 | . 00266 | . 00400 | . 00033 | . 04233 | . 00233 |
| 73, 000 | . 04967 | . 00334 | . 00433 | . 00033 | . 04533 | . 00300 |
| 74, 000 | . 05200 | . 00233 | . 00400 | —. 00033 | . 04800 | . 00267 |
| 75, 000 | . 05500 | . 00300 | . 00433 | . 00033 | . 05067 | . 00267 |
| 76, 000 | . 05933 | . 00433 | . 00467 | . 00034 | . 05467 | . 00400 |
| 77, 000 | . 06433 | . 00500 | . 00500 | . 00033 | . 05933 | . 00466 |
| 78, 000 | . 06800 | . 00367 | . 00467 | —. 00033 | . 06333 | . 00400 |
| 79, 000 | . 07367 | . 00567 | . 00467 | . 00000 | . 06900 | . 00567 |
| 80, 000 | . 07967 | . 00600 | . 00467 | . 00000 | . 07500 | . 00600 |
| 81, 000 | . 08700 | . 00733 | . 00500 | . 00033 | . 08200 | . 00700 |
| 82, 000 | . 09667 | . 00967 | . 00533 | . 00033 | . 09133 | . 00933 |
| 83, 000 | . 10867 | . 01200 | . 00533 | . 00000 | . 10333 | . 01200 |
| 84, 000 | . 12433 | . 01566 | . 00533 | . 00000 | . 11900 | . 01567 |
| 85, 000 | . 14867 | . 02434 | 0. 00633 | 0. 00100 | 0. 14233 | 0. 02333 |
| 86, 000 | 0. 25400 | 0. 10533 | (*) | (*) | (*) | (*) |

* Specimen broke.

GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | |
| Tensile strength, per square inch ........ pounds.. | 86, 000 |
| Elastic limit ........ pounds.. | 47, 000 |
| Extension, per inch, at elastic limit ........ inch.. | 0. 00333 |
| Extension, per inch, at rupture ........ inch.. | 0. 25400 |
| Hardness | |
| Original area of cross-section ........ square inch.. | 0. 3038 |
| Area after rupture ........ square inch.. | 0. 1534 |
| Position of rupture ........ | about 1 inch from upper shoulder |
| Character of fracture ........ | fine fibrous |

SPECIMEN I.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel* 3 *inches long (between the shoulders) and* 0.622 *inches diameter, taken from breech-receiver No.* 4, *for* 8-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 4, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 5, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 6, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 7, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 8, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 9, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 10, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 11, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 12, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 13, 000 | . 00033 | . 00033 | . 00033 | . 00033 | . 00000 | . 00000 |
| 14, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 15, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 16, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 17, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 18, 000 | . 00067 | . 00034 | . 00067 | . 00034 | . 00000 | . 00000 |
| 19, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 20, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 21, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 22, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 23, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 24, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 25, 000 | . 00100 | . 00033 | . 00100 | . 00033 | . 00000 | . 00000 |
| 26, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 27, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 28, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 29, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 30, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 31, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 32, 000 | . 00133 | . 00033 | . 00133 | . 00033 | . 00000 | . 00000 |
| 33, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 34, 000 | . 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 35, 000 | . 00133 | . 00000 | . 00133 | 00000 | . 00000 | . 00000 |
| 36, 000 | 00133 | . 00000 | . 00133 | . 00000 | . 00000 | . 00000 |
| 37, 000 | . 00167 | . 00034 | . 00167 | . 00034 | . 00000 | . 00000 |
| 38, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 39, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 40, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 41, 000 | . 00167 | . 00000 | . 00167 | . 00000 | . 00000 | . 00000 |
| 42, 000 | . 00200 | . 00033 | . 00200 | . 00033 | . 00000 | . 00000 |
| 43, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 44, 000 | . 00200 | . 00000 | . 00200 | . 00000 | . 00000 | . 00000 |
| 45, 000 | . 00200 | . 00000 | . 00167 | — . 00033 | . 00033 | . 00033 |
| 46, 000 | . 00233 | . 00033 | . 00167 | . 00000 | . 00067 | . 00034 |
| 47, 000 | . 00367 | . 00134 | . 00133 | . 00034 | . 00233 | . 00166 |
| 48, 000 | . 00600 | . 00233 | . 00233 | . 00100 | . 00367 | . 00134 |
| 49, 000 | . 01000 | . 00400 | . 00367 | . 00134 | . 00633 | . 00266 |
| 50, 000 | . 01233 | . 00233 | . 00267 | — . 00100 | . 00967 | . 00334 |
| 51, 000 | . 01333 | . 00100 | . 00267 | . 00000 | . 01067 | . 00100 |
| 52, 000 | . 01400 | . 00067 | . 00267 | . 00000 | . 01133 | . 00066 |

SPECIMEN I.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 53,000 | 0.01600 | 0.00200 | 0.00267 | 0.00000 | 0.01383 | 0.00200 |
| 54,000 | .01700 | .00100 | .00267 | .00000 | .01483 | 00100 |
| 55,000 | .01800 | .00100 | .00267 | .00000 | .01533 | .00100 |
| 56,000 | .01833 | .00033 | .00267 | .00000 | .01567 | .00034 |
| 57,000 | .01967 | .00133 | .00300 | .00033 | .01667 | .00100 |
| 58,000 | .02033 | .00066 | .00300 | .00000 | .01783 | .00066 |
| 59,000 | .02200 | .00167 | .00300 | .00000 | .01900 | .00167 |
| 60,000 | .02367 | .00167 | .00333 | .00033 | .02033 | .00133 |
| 61,000 | .02567 | .00200 | .00333 | .00000 | .02233 | .00200 |
| 62,000 | .02633 | .00066 | .00300 | — .00033 | .02333 | .00100 |
| 63,000 | .02833 | .00200 | .00300 | .00000 | .02533 | .00200 |
| 64,000 | .03000 | .00167 | .00333 | .00033 | .02667 | .00134 |
| 65,000 | .03167 | .00167 | .00333 | .00000 | .02833 | .00166 |
| 66,000 | .03333 | .00166 | .00333 | .00000 | .03000 | .00167 |
| 67,000 | .03567 | .00234 | .00367 | .00034 | .03200 | .00200 |
| 68,000 | .03800 | .00233 | .00367 | .00000 | .03433 | .00233 |
| 69,000 | .04200 | .00400 | .00367 | .00000 | .03833 | .00400 |
| 70,000 | .04333 | .00133 | .00400 | .00033 | .03933 | .00100 |
| 71,000 | .04600 | .00267 | .00400 | .00000 | .04200 | .00267 |
| 72,000 | .04833 | .00233 | .00367 | — .00033 | .04467 | .00267 |
| 73,000 | .05100 | .00267 | .00400 | .00033 | .04700 | .00233 |
| 74,000 | .05567 | .00467 | .00400 | .00000 | .05167 | .00467 |
| 75,000 | .05867 | .00300 | .00433 | .00033 | .05433 | .00266 |
| 76,000 | .06400 | .00533 | .00400 | — .00033 | .06000 | .00567 |
| 77,000 | .06733 | .00333 | .00433 | .00033 | .06300 | .00300 |
| 78,000 | .07067 | .00334 | .00433 | .00000 | .06633 | .00333 |
| 79,000 | .07667 | .00600 | .00267 | — .00166 | .07400 | .00767 |
| 80,000 | .08400 | .00733 | .00433 | .00166 | .07967 | .00567 |
| 81,000 | .09367 | .00967 | .00500 | .00067 | .08867 | .00900 |
| 82,000 | .10433 | .01066 | .00500 | .00000 | .09933 | .01066 |
| 83,000 | .11933 | .01500 | .00500 | .00000 | .11433 | .01500 |
| 84,000 | .14667 | .02734 | 0.00500 | 0.00000 | 0.14167 | 0.02734 |
| 85,000 | 0.24900 | 0.10233 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7.[illegible] |
| Tensile strength, per square inch ........ pounds.. | 85,[illegible] |
| Elastic limit ........ pounds.. | 45,[illegible] |
| Extension, per inch, at elastic limit ........ inch.. | 0.00[illegible] |
| Extension, per inch, at rupture ........ inch.. | 0.249[illegible] |
| Hardness | 17.[illegible] |
| Original area of cross-section ........ square inch.. | 0.[illegible] |
| Area after rupture ........ square inch.. | 0.1647 |
| Position of rupture | [illegible] from shoulder. |
| Character of fracture | fibrous; slightly crystallized; bright. |

SPECIMEN II.—*Table showing the extension, restoration, and permanent set per inch, in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel,* 3 *inches long (between shoulders) and* 0.620 *inches diameter, taken from breech-receiver No.* 4, *for* 8-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 6,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 7,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 8,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 9,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 10,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 11,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 12,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 13,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 14,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 15,009 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 16,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 17,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 18,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 19,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 20,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 21,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 22,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 23,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 24,000 | .00133 | .00033 | .00133 | .00033 | .00000 | .00000 |
| 25,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 26,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 27,000 | .00167 | .00034 | .00167 | .00034 | .00000 | .00000 |
| 28,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 29,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 30,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 31,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 32,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 33,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 34,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 35,000 | .00200 | .00033 | .00200 | .00033 | .00000 | .00000 |
| 36,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 37,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 38,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 39,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 40,000 | .00200 | .00000 | .00200 | .00000 | .00000 | .00000 |
| 41,000 | .00233 | .00033 | .00233 | .00033 | .00000 | .00000 |
| 42,000 | .00233 | .00000 | .00233 | .00000 | .00000 | .00000 |
| 43,000 | .00233 | .00000 | .00200 | —.00033 | .00063 | .00033 |
| 44,000 | .00367 | .00134 | .00200 | .00000 | .00167 | .00134 |
| 45,000 | .00667 | .00300 | .00200 | .00000 | .00467 | .00300 |
| 46,000 | .00833 | .00166 | .00200 | .00000 | .00633 | .00166 |
| 47,000 | .01800 | .00467 | .00367 | .00167 | .00933 | .00300 |
| 48,000 | .01400 | .00100 | .00267 | —.00100 | .01133 | .00200 |
| 49,000 | .01600 | .00200 | .00267 | .00000 | .01333 | .00200 |
| 50,000 | .01833 | .00233 | .00300 | .00033 | .01533 | .00200 |
| 51,000 | .01933 | .00100 | .00300 | .00000 | .01633 | .00100 |
| 52,000 | .02000 | .00067 | .00267 | —.00033 | .01733 | .00100 |
| 53,000 | .02067 | .00067 | .00300 | .00033 | .01767 | .00034 |
| 54,000 | .02267 | .00200 | .00300 | .00000 | .01967 | .00200 |
| 55,000 | .02433 | .00166 | .00333 | .00033 | .02100 | .00133 |
| 56,000 | .02533 | .00100 | .00333 | .00000 | .02200 | .00100 |
| 57,000 | .02633 | .00100 | .00333 | .00000 | .02300 | .00100 |
| 58,000 | .02033 | .00300 | .00500 | .00167 | .02433 | .00133 |
| 59,000 | .02933 | .00000 | .00300 | —.00200 | .02633 | .00200 |
| 60,000 | .03200 | .00267 | .00333 | .00033 | .02867 | .00234 |
| 61,000 | .03367 | .00167 | .00367 | .00034 | .03000 | .00133 |
| 62,000 | .03600 | .00233 | .00367 | .00000 | .03233 | .00233 |
| 63,000 | .03700 | .00100 | .00300 | —.00067 | .03400 | .00167 |
| 64,000 | .03833 | .00133 | .00333 | .00033 | .03500 | .00100 |
| 65,000 | .04000 | .00167 | .00333 | .00000 | .03667 | .00167 |
| 66,000 | .04233 | .00233 | .00367 | .00034 | .03867 | .00200 |

SPECIMEN II.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 67, 000 | 0. 04533 | 0. 00300 | 0. 00400 | 0. 00033 | 0. 04133 | 0. 00266 |
| 68, 000 | . 04600 | . 00067 | . 00200 | — . 00200 | . 04400 | . 00267 |
| 69, 000 | . 05100 | . 00500 | . 00433 | . 00233 | . 04667 | . 00267 |
| 70, 000 | . 05367 | . 00267 | . 00433 | . 00000 | . 04933 | . 00266 |
| 71, 000 | . 05733 | . 00366 | . 00400 | — . 00033 | . 05333 | . 00400 |
| 72, 000 | . 06133 | . 00400 | . 00400 | . 00000 | . 05733 | . 00400 |
| 73, 000 | . 06567 | . 00434 | . 00433 | . 00033 | . 06133 | . 00400 |
| 74, 000 | . 07033 | . 00466 | . 00433 | . 00000 | . 06600 | . 00467 |
| 75, 000 | . 07667 | . 00634 | . 00467 | . 00034 | . 07200 | . 00600 |
| 76, 000 | . 08467 | . 00800 | . 00433 | — . 00034 | . 08033 | . 00833 |
| 77, 000 | . 09167 | . 00700 | . 00500 | . 00067 | . 08667 | . 00634 |
| 78, 000 | . 10267 | . 01100 | . 00467 | — . 00033 | . 09800 | . 01133 |
| 79, 000 | . 11933 | . 01666 | 0. 00467 | 0. 00000 | 0. 11467 | 0. 01667 |
| 80, 000 | 0. 21567 | 0. 09634 | (*) | (*) | (*) | (*) |

* Specimen broke.

GENERAL SUMMARY

| | |
|---|---|
| Specific gravity | 7. 8233 |
| Tensile strength, per square inch ... pounds | 80, 000 |
| Elastic limit ... pounds | 43, 000 |
| Extension, per inch, at elastic limit ... inches | 0. 00233 |
| Extension, per inch, at rupture ... inches | 0. 21567 |
| Hardness | 17. 535 |
| Original area of cross-section ... square inch | 0. 3019 |
| Area after rupture ... square inch | 0. 1878 |
| Position of rupture | ½ from shoulder. |
| Character of fracture | very fine (pot-holed) and small crystals scattered throughout. |

SPECIMEN I.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel,* 3 *inches long (between shoulders), and* 0.622 *inches diameter, taken from breech-receiver No.* 5, *for* 8-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 4, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 5, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 6, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 7, 000 | . 00033 | . 00033 | . 00033 | . 00033 | . 00000 | . 00000 |
| 8, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 9, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 10, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 11, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 12, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 13, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 14, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 15, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 16, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 17, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 18, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 19, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |

SPECIMEN I.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch in section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 20, 000 | 0. 00033 | 0. 00000 | 0. 00033 | 0. 00000 | 0. 00000 | 0. 00000 |
| 21, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 22, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 23, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 24, 000 | . 00033 | . 00000 | . 00038 | . 00000 | . 00000 | . 00000 |
| 25, 000 | . 00033 | 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 26, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 27, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 28, 000 | . 00067 | . 00034 | . 00067 | . 00034 | . 00000 | . 00000 |
| 29, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 30, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 31, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 32, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 33, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 34, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 35, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 36, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 37, 000 | . 00100 | . 00033 | . 00100 | . 00033 | . 00000 | . 00000 |
| 38, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 39, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 40, 000 | . 00300 | . 00200 | . 00200 | . 00100 | . 00100 | . 00100 |
| 41, 000 | . 00533 | . 00233 | . 00160 | — . 00033 | . 00367 | . 00267 |
| 42, 000 | . 01100 | . 00567 | . 00207 | . 00033 | . 00900 | . 00533 |
| 43, 000 | . 01200 | . 00100 | . 00200 | . 00000 | . 01000 | . 00100 |
| 44, 000 | . 01333 | . 00133 | . 00230 | . 00033 | . 01100 | . 00100 |
| 45, 000 | . 01400 | . 00067 | . 00233 | . 00000 | . 01167 | . 00067 |
| 46, 000 | . 01467 | . 00067 | . 00203 | — . 00033 | . 01267 | . 00100 |
| 47, 000 | . 01567 | . 00100 | . 00230 | . 00033 | . 01333 | . 00066 |
| 48, 000 | . 01667 | . 00100 | . 00203 | — . 00033 | . 01467 | . 00134 |
| 49, 000 | . 01733 | . 00066 | . 00200 | . 00000 | . 01533 | . 00066 |
| 50, 000 | . 01900 | . 00167 | . 00230 | . 00033 | . 01667 | . 00134 |
| 51, 000 | . 02100 | . 00200 | . 00233 | . 00000 | . 01867 | . 00200 |
| 52, 600 | . 02300 | . 00200 | . 00263 | . 00034 | . 02033 | . 00166 |
| 53, 000 | . 02467 | . 00167 | . 00267 | . 00000 | . 02167 | . 00134 |
| 54, 000 | . 02533 | . 00066 | . 00237 | — . 00034 | . 02300 | . 00133 |
| 55, 000 | . 02667 | . 00134 | . 00233 | . 00000 | . 02433 | . 00133 |
| 56, 000 | . 02933 | . 00266 | . 00263 | . 00034 | . 02667 | . 00234 |
| 57, 000 | . 03167 | . 00234 | . 00267 | . 00000 | . 02900 | . 00367 |
| 58, 000 | . 03400 | . 00233 | . 00267 | . 00000 | . 03133 | . 00233 |
| 59, 000 | . 03700 | . 00300 | . 00337 | . 00067 | . 03367 | . 00234 |
| 60, 000 | . 03933 | . 00233 | . 00303 | — . 00033 | . 03633 | . 00266 |
| 61, 000 | . 04133 | . 00200 | . 00300 | . 00000 | . 03833 | . 00200 |
| 62, 000 | . 04433 | . 00300 | . 00300 | . 00000 | . 04133 | . 00300 |
| 63, 000 | . 04800 | . 00367 | . 00367 | . 00067 | . 04433 | . 00300 |
| 64, 000 | . 05167 | . 00367 | . 00333 | — . 00034 | . 04833 | , 00400 |
| 65, 000 | . 05600 | . 00433 | . 00333 | . 00000 | . 05267 | . 00434 |
| 66, 000 | . 06133 | . 00533 | . 00333 | . 00000 | . 05800 | . 00533 |
| 67, 000 | . 06600 | . 00533 | . 00300 | — . 00033 | . 06300 | . 00500 |
| 68, 000 | . 07467 | . 00867 | . 00367 | . 00067 | . 07100 | . 00800 |
| 69, 000 | . 07933 | . 00466 | . 00367 | . 00000 | . 07233 | . 00133 |
| 70, 000 | . 08933 | . 01000 | . 00400 | . 00033 | . 08533 | . 01300 |
| 71, 000 | . 10067 | . 01134 | . 00367 | — . 00033 | . 09700 | . 01167 |
| 72, 000 | . 11367 | . 01300 | . 00433 | . 00066 | . 10933 | . 01233 |
| 73, 000 | . 13400 | . 02033 | 0. 00407 | —0. 00033 | 0. 13000 | 0. 02067 |
| 74, 000 | 0. 25433 | 0. 12033 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity (mean of three results) | 7. 9002 |
| Tensile strength, per square inch .......... pounds.. | 74, 000 |
| Elastic limit .......... pounds.. | 40, 000 |
| Extension, per inch, at elastic limit .......... inch.... | 0. 00300 |
| Extension, per inch, at rupture .......... inch.... | 0. 25433 |
| Hardness (mean of three results) | 14. 73 |
| Original area of cross-section .......... square inch.... | 0. 3038 |
| Area after rupture .......... square inch.... | 0. 1723 |
| Position of rupture | ⅓ from shoulder. |
| Character of fracture | fine fibrous. |

SPECIMEN II.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the under-mentioned weights, per square inch of section, acting on a solid cylinder of steel 3 inches long (between shoulders) and 0.622 inches diameter, taken from breech-receiver No. 5, for 8-inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 9,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 10,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 11,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 12,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 13,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 14,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 15,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 16,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 17,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 18,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 19,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 20,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 21,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 22,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 23,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 24,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 25,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 26,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 27,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 28,000 | .00133 | .00066 | .00133 | .00066 | .00000 | .00000 |
| 29,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 30,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 31,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 32,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 33,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 34,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 35,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 36,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 37,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 38,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 39,000 | .00167 | .00034 | .00167 | .00034 | .00000 | .00000 |
| 40,000 | .00200 | .00033 | .00133 | — .00034 | .00067 | .00067 |
| 41,000 | .00300 | .00100 | .00133 | .00000 | .00167 | .00100 |
| 42,000 | .00467 | .00167 | .00167 | .00034 | .00300 | .00133 |
| 43,000 | .00667 | .00200 | .00167 | .00000 | .00500 | .00200 |
| 44,000 | .01300 | .00633 | .00167 | .00000 | .01133 | .00633 |
| 45,000 | .01500 | .00200 | .00167 | .00000 | .01333 | .00200 |
| 46,000 | .01633 | .00133 | .00200 | .00033 | .01433 | .00100 |
| 47,000 | .01767 | .00134 | .00167 | — .00033 | .01600 | .00167 |
| 48,000 | .01900 | .00133 | .00233 | .00066 | .01667 | .00067 |
| 49,000 | .02000 | .00100 | .00233 | .00000 | .01767 | .00100 |
| 50,000 | .02133 | .00133 | .00233 | .00000 | .01900 | .00133 |
| 51,000 | .02300 | .00167 | .00233 | .00000 | .02067 | .00167 |
| 52,000 | .02467 | .00167 | .00233 | .00000 | .02233 | .00166 |
| 53,000 | .02633 | .00166 | .00267 | .00034 | .02367 | .00134 |
| 54,000 | .02800 | .00167 | .00333 | .00066 | .02467 | .00100 |
| 55,000 | .03000 | .00200 | .00433 | .00100 | .02567 | .00100 |
| 56,000 | .03200 | .00200 | .00267 | — .00166 | .02700 | .00133 |
| 57,000 | .03433 | .00233 | .00267 | .00000 | .03167 | .00467 |
| 58,000 | .03700 | .00267 | .00300 | .00033 | .03400 | .00233 |
| 59,000 | .03967 | .00267 | .00267 | — .00033 | .03700 | .00300 |
| 60,000 | .04167 | .00200 | .00267 | .00000 | .03900 | .00200 |
| 61,000 | .04533 | .00366 | .00267 | .00000 | .04267 | .00367 |
| 62,000 | .04867 | .00334 | .00333 | .00066 | .04533 | .00266 |
| 63,000 | .05200 | .00333 | .00300 | — .00033 | .04900 | .00367 |
| 64,000 | .05600 | .00400 | .00300 | .00000 | .05300 | .00400 |
| 65,000 | .06067 | .00467 | .00333 | .00033 | .05733 | .00433 |
| 66,000 | .06567 | .00500 | .00300 | — .00033 | .06267 | .00534 |
| 67,000 | .07267 | .00700 | .00300 | .00000 | .06967 | .00700 |

SPECIMEN II.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 68, 000 | 0. 07933 | 0. 00666 | 0. 00367 | 0. 00067 | 0. 07567 | 0. 00600 |
| 69, 000 | . 08633 | . 00700 | . 00333 | — . 00034 | . 08300 | . 00733 |
| 70, 000 | . 09600 | . 00967 | . 00400 | . 00067 | . 09200 | . 00900 |
| 71, 000 | . 10833 | . 01233 | . 00367 | — . 00033 | . 10467 | . 01267 |
| 72, 000 | . 12283 | . 01400 | . 00367 | . 00000 | . 11867 | . 01400 |
| 73, 000 | . 14667 | . 02434 | 0. 00367 | 0. 00000 | 0. 14300 | 0. 02433 |
| 74, 000 | 0. 26133 | 0. 11466 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity (mean of three results) | 7. 9002 |
| Tensile strength, per square inch ....pounds.. | 74, 000 |
| Elastic limit ....pounds.. | 40, 000 |
| Extension, per inch, at elastic limit ....inch.. | 0. 00200 |
| Extension, per inch, at rupture ....inch.. | 0. 26133 |
| Hardness (mean of three results) | 14. 73 |
| Original area of cross-section ....square inch.. | 0. 3038 |
| Area after rupture ....square inch.. | 0. 1832 |
| Position of rupture | ¼ from shoulder. |
| Character of fracture | close fibrous. |

SPECIMEN III.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel,* 6 *inches long (between shoulders) and* 0.628 *inches diameter, taken from breech-receiver No.* 5, *for* 8-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 4, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 5, 000 | . 00017 | . 00017 | . 00017 | . 00017 | . 00000 | . 00000 |
| 6, 000 | . 00017 | . 00000 | . 00017 | . 00000 | . 00000 | . 00000 |
| 7, 000 | . 00017 | . 00000 | . 00017 | . 00000 | . 00000 | . 00000 |
| 8, 000 | . 00017 | . 00000 | . 00017 | . 00000 | . 00000 | . 00000 |
| 9, 000 | . 00017 | . 00000 | . 00017 | . 00000 | . 00000 | . 00000 |
| 10, 000 | . 00033 | . 00016 | . 00033 | . 00016 | . 00000 | . 00000 |
| 11, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 12, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 13, 000 | . 00050 | . 00017 | . 00050 | . 00017 | . 00000 | . 00000 |
| 14, 000 | . 00050 | . 00000 | . 00050 | . 00000 | . 00000 | . 00000 |
| 15, 000 | . 00050 | . 00000 | . 00050 | . 00000 | . 00000 | . 00000 |
| 16, 000 | . 00050 | . 00000 | . 00050 | . 00000 | . 00000 | . 00000 |
| 17, 000 | . 00050 | . 00000 | . 00050 | . 00000 | . 00000 | . 00000 |
| 18, 000 | . 00067 | . 00017 | . 00067 | . 00017 | . 00000 | . 00000 |
| 19, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 20, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 21, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 22, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 23, 000 | . 00083 | . 00016 | . 00083 | . 00016 | . 00000 | . 00000 |
| 24, 000 | . 00083 | . 00000 | . 00083 | . 00000 | . 00000 | . 00000 |
| 25, 000 | . 00083 | . 00000 | . 00083 | . 00000 | . 00000 | . 00000 |

SPECIMEN III.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 26,000 | 0.00083 | 0.00000 | 0.00083 | 0.00000 | 0.00000 | 0.00000 |
| 27,000 | .00100 | .00017 | .00100 | .00017 | .00000 | .00000 |
| 28,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 29,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 30,000 | .00117 | .00017 | .00117 | .00017 | .00000 | .00000 |
| 31,000 | .00117 | .00000 | .00117 | .00000 | .00000 | .00000 |
| 32,000 | .00117 | .00000 | .00117 | .00000 | .00000 | .00000 |
| 33,000 | .00117 | .00000 | .00117 | .00000 | .00000 | .00000 |
| 34,000 | .00117 | .00000 | .00117 | .00000 | .00000 | .00000 |
| 35,000 | .00117 | .00000 | .00117 | .00000 | .00000 | .00000 |
| 36,000 | .00133 | .00016 | .00133 | .00016 | .00000 | .00000 |
| 37,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 38,000 | .00150 | .00017 | .00150 | .00017 | .00000 | .00000 |
| 39,000 | .00150 | .00000 | .00150 | .00000 | .00000 | .00000 |
| 40,000 | .00150 | .00000 | .00150 | .00000 | .00000 | .00000 |
| 41,000 | .00150 | .00000 | .00150 | .00000 | .00000 | .00000 |
| 42,000 | .00167 | .00017 | .00167 | .00017 | .00000 | .00000 |
| 43,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 44,000 | .00183 | .00016 | .00183 | .00016 | .00000 | .00000 |
| 45,000 | .00283 | .00100 | .00183 | .00000 | .00100 | .00100 |
| 46,000 | .00367 | .00084 | .00183 | .00000 | .00183 | .00083 |
| 47,000 | .00633 | .00266 | .00183 | .00000 | .00450 | .00267 |
| 48,000 | .00950 | .00317 | .00217 | .00034 | .00733 | .00283 |
| 49,000 | .01217 | .00267 | .00267 | .00050 | .00950 | .00217 |
| 50,000 | .01267 | .00050 | .00250 | —.00017 | .01017 | .00067 |
| 51,000 | .01383 | .00116 | .00267 | .00017 | .01117 | .00100 |
| 52,000 | .01450 | .00067 | .00267 | .00000 | .01183 | .00066 |
| 53,000 | .01533 | .00083 | .00250 | —.00017 | .01283 | .00100 |
| 54,000 | .01650 | .00117 | .00300 | .00050 | .01350 | .00067 |
| 55,000 | .01750 | .00100 | .00267 | —.00033 | .01483 | .00133 |
| 56,000 | .01850 | .00100 | .00267 | .00000 | .01583 | .00100 |
| 57,000 | .01950 | .00100 | .00267 | .00000 | .01683 | .00100 |
| 58,000 | .02100 | .00150 | .00300 | .00033 | .01800 | .00117 |
| 59,000 | .02233 | .00133 | .00317 | .00017 | .01917 | .00117 |
| 60,000 | .02350 | .00117 | .00267 | —.00050 | .02083 | .00166 |
| 61,000 | .02500 | .00150 | .00300 | .00033 | .02200 | .00117 |
| 62,000 | .02633 | .00133 | .00300 | .00000 | .02333 | .00133 |
| 63,000 | .02817 | .00184 | .00300 | .00000 | .02517 | .00184 |
| 64,000 | .03033 | .00216 | .00317 | .00017 | .02717 | .00200 |
| 65,000 | .03233 | .00200 | .00350 | .00033 | .02883 | .00166 |
| 66,000 | .03400 | .00167 | .00333 | —.00017 | .03067 | .00184 |
| 67,000 | .03633 | .00233 | .00333 | .00000 | .03300 | .00233 |
| 68,000 | .03850 | .00217 | .00333 | .00000 | .03517 | .00217 |
| 69,000 | .04067 | .00217 | .00350 | .00017 | .03717 | .00200 |
| 70,000 | .04367 | .00300 | .00367 | .00017 | .04000 | .00283 |
| 71,000 | .04750 | .00383 | .00383 | .00016 | .04367 | .00367 |
| 72,000 | .05117 | .00367 | .00383 | .00000 | .04733 | .00366 |
| 73,000 | .05500 | .00383 | .00400 | .00017 | .05100 | .00367 |
| 74,000 | .05917 | .00417 | .00383 | —.00017 | .05533 | .00433 |
| 75,000 | .06367 | .00450 | .00400 | .00017 | .05967 | .00434 |
| 76,000 | .06850 | .00483 | .00417 | .00017 | .06443 | .00476 |
| 77,000 | .07517 | .00667 | .00467 | .00050 | .07050 | .00607 |
| 78,000 | .08267 | .00750 | .00467 | .00000 | .07800 | .00750 |
| 79,000 | .09217 | .00950 | .00433 | —.00034 | .08783 | .00983 |
| 80,000 | .10433 | .01216 | .00533 | .00100 | .09900 | .01117 |
| 81,000 | .12633 | .02200 | 0.00083 | —0.00450 | 0.12550 | 0.02650 |
| 82,000 | 0.17100 | 0.04467 | (*) | (*) | (*) | (*) |

*Specimen broke.

## GENERAL SUMMARY.

Specific gravity (of half specimen after testing) .......... 7.8[illegible]
Tensile strength, per square inch .......... pounds.. 82,0[illegible]
Elastic limit .......... pounds.. 45,0[illegible]
Extension, per inch, at elastic limit .......... inch.. 0.00[illegible]
Extension, per inch, at rupture .......... inch.. 0.17100
Hardness (of half specimen after testing) .......... 18.981
Original area of cross-section .......... square inch.. 0.3097
Area after rupture .......... square inch.. 0.1676
Position of rupture .......... about 1 inch from shoulder
Character of fracture .......... close fibrous

SPECIMEN IV.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel,* 6 *inches long (between shoulders) and* 0.628 *inch diameter taken from breech-receiver No.* 5, *for* 8-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00017 | .00017 | .00017 | .00017 | .00000 | .00000 |
| 6,000 | .00017 | .00000 | .00017 | .00000 | .00000 | .00000 |
| 7,000 | .00017 | .00000 | .00017 | .00000 | .00000 | .00000 |
| 8,000 | .00033 | .00016 | .00033 | .00016 | .00000 | .00000 |
| 9,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 10,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 11,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 12,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 13,000 | .00050 | .01017 | .00050 | .00017 | .00000 | .00000 |
| 14,000 | .00050 | .00000 | .00050 | .00000 | .00000 | .00000 |
| 15,000 | .00067 | .00017 | .00067 | .00017 | .00000 | .00000 |
| 16,000 | .00067 | .00000 | .00067 | .06000 | .00000 | .00000 |
| 17,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 18,000 | .00083 | .00016 | .00083 | .00016 | .00000 | .00000 |
| 19,000 | .00083 | .00000 | .00083 | .00000 | .00000 | .00000 |
| 20,000 | .00083 | .00000 | .00083 | .00000 | .00000 | .00000 |
| 21,000 | .00083 | .00000 | .00083 | .00000 | .00000 | .00000 |
| 22,000 | .00083 | .00000 | .00083 | .00000 | .00000 | .00000 |
| 23,000 | .00083 | .00000 | .00083 | .00000 | .00000 | .00000 |
| 24,000 | .00100 | .00017 | .00100 | .00017 | .00000 | .00000 |
| 25,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 26,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 27,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 28,000 | .00117 | .00017 | .00117 | .00017 | .00000 | .00000 |
| 29,000 | .00117 | .00000 | .00117 | .00000 | .00000 | .00000 |
| 30,000 | .00117 | .00000 | .00117 | .00000 | .00000 | .00000 |
| 31,000 | .00133 | .00016 | .00133 | .00016 | .00000 | .00000 |
| 32,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 33,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 34,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 35,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 36,000 | .00150 | .00017 | .00150 | .00017 | .00000 | .00000 |
| 37,000 | .00150 | .00000 | .00150 | .00000 | .00000 | .00000 |
| 38,000 | .00150 | .00000 | .00150 | .00000 | .00000 | .00000 |
| 39,000 | .00150 | .00000 | .00150 | .00000 | .00000 | .00000 |
| 40,000 | .00167 | .00017 | .00167 | .00017 | .00000 | .00000 |
| 41,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 42,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 43,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 44,000 | .00167 | .00000 | .00167 | .00000 | .00009 | .00000 |
| 45,000 | .00167 | .00000 | .00167 | .00000 | .00000 | .00000 |
| 46,000 | .00183 | .00016 | .00183 | .00016 | .00000 | .00000 |
| 47,000 | .00183 | .00000 | .00117 | —.00066 | .00067 | .00067 |
| 48,000 | .01217 | .01334 | .00250 | .00133 | .00967 | .00900 |
| 49,000 | .01267 | .00050 | .00233 | —.00017 | .01033 | .00066 |
| 50,000 | .01333 | .00066 | .00217 | —.00016 | .01117 | .00084 |
| 51,000 | .01400 | .00067 | .00250 | .00033 | .01150 | .00033 |
| 52,000 | .01483 | .00083 | .00250 | .00000 | .01233 | .00083 |
| 53,000 | .01600 | .00117 | .00250 | .00000 | .01350 | .00117 |
| 54,000 | .01750 | .00150 | .00300 | .00050 | .01450 | .00100 |
| 55,000 | .01850 | .00100 | .00283 | —.00017 | .01567 | .00117 |
| 56,000 | .01967 | .00117 | .00283 | .00000 | .01683 | .00116 |
| 57,000 | .02083 | .00116 | .00283 | .00000 | .01800 | .00117 |
| 58,000 | .02250 | .00167 | .00300 | .00017 | .01950 | .00150 |
| 59,000 | .02383 | .00133 | .00300 | .00000 | .02083 | .00133 |
| 60,000 | .02550 | .00167 | .00300 | .00000 | .02250 | .00167 |
| 61,000 | .02683 | .00133 | .00283 | —.00017 | .02400 | .00150 |
| 62,000 | .02883 | .00200 | .00317 | .00034 | .02567 | .00167 |
| 63,000 | .03083 | .00200 | .00300 | —.00017 | .02783 | .00216 |
| 64,000 | .03283 | .00200 | .00317 | .00017 | .02967 | .00184 |
| 65,000 | .03567 | .00284 | .00350 | .00033 | .03217 | .00250 |
| 66,000 | .03783 | .00216 | .00300 | —.00050 | .03483 | .00266 |
| 67,000 | .04083 | .00300 | .00350 | .00050 | .03733 | .00250 |

SPECIMEN IV.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 68,000 | 0.04400 | 0.00317 | 0.00383 | 0.00033 | 0.04017 | 0.00274 |
| 69,000 | .04617 | .00217 | .00367 | —.00016 | .04250 | .00233 |
| 70,000 | .04983 | .00366 | .00383 | .00016 | .04450 | .00200 |
| 71,000 | .05400 | .00417 | .00400 | .00017 | .05000 | .00550 |
| 72,000 | .05800 | .00400 | .00367 | —.00033 | .05433 | .00433 |
| 73,000 | .06283 | .00483 | .00400 | .00033 | .05883 | .00450 |
| 74,000 | .06900 | .00617 | .00417 | .00017 | .06483 | .00600 |
| 75,000 | .07567 | .00667 | .00450 | .00033 | .07117 | .00634 |
| 76,000 | .08317 | .00750 | .00433 | —.00017 | .07883 | .00766 |
| 77,000 | .09250 | .00933 | 0.00433 | 0.00000 | 0.08817 | 0.00934 |
| 78,000 | 0.09817 | 0.00567 | (*) | (*) | (*) | (*) |

*Specimen broke.

GENERAL SUMMARY.

Specific gravity (of half specimen after testing) .......... 7.8566
Tensile strength, per square inch .......... pounds.. 78,0[illegible]
Elastic limit .......... pounds.. 47,000
Extension, per inch, at elastic limit .......... inch.. 0.0[illegible]
Extension, per inch, at rupture .......... inch.. 0.09[illegible]17
Hardness (of half specimen after testing) .......... 21 16[illegible]
Original area of cross-section .......... square inch.. 0.30[illegible]
Area after rupture .......... square inch range.. 0.2[illegible]
Position of rupture .......... 2¼ from shoulder.
Character of fracture: crystalline, radiating from small spot of much finer structure on one side of specimen.

SPECIMEN V.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel 3 inches long (between shoulders) and 0.622 inch diameter, taken from breech-receiver No. 5, for 8-inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | [illegible] |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | [illegible] |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | [illegible] |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | [illegible] |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | [illegible] |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | [illegible] |
| 7,000 | .00000 | .00000 | .00000 | .00000 | .00000 | [illegible] |
| 8,000 | .00000 | .00000 | .00000 | .00000 | .00000 | [illegible] |
| 9,000 | .00000 | .00000 | .00000 | .00000 | .00000 | [illegible] |
| 10,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 11,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 12,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 13,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 14,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 15,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 16,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 17,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 18,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 19,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 20,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 21,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |

SPECIMEN V.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 22,000 | 0.00067 | 0.00034 | 0.00067 | 0.00034 | 0.00000 | 0.00000 |
| 23,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 24,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 25,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 26,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 27,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 28,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 29,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 30,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 31,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 32,000 | .00133 | .00033 | .00133 | .00033 | .00000 | .00000 |
| 33,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 34,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 35,000 | .00200 | .00067 | .00100 | — .00033 | .00100 | .00100 |
| 36,000 | .00300 | .00100 | .00100 | .00000 | .00200 | .00100 |
| 37,000 | .00467 | .00167 | .00167 | .00067 | .00300 | .00100 |
| 38,000 | .00700 | .00233 | .00167 | .00000 | .00533 | .00233 |
| 39,000 | .00933 | .00233 | .00167 | .00000 | .00767 | .00234 |
| 40,000 | .01033 | .00100 | .00167 | .00000 | .00867 | .00100 |
| 41,000 | .01033 | .00000 | .00167 | .00000 | .00867 | .00000 |
| 42,000 | .01233 | .00200 | .00267 | .00100 | .00967 | .00100 |
| 43,000 | .01300 | .00067 | .00200 | — .00067 | .01100 | .00133 |
| 44,000 | .01433 | .00133 | .00200 | .00000 | .01233 | .00133 |
| 45,000 | .01500 | .00067 | .00167 | — .00033 | .01333 | .00100 |
| 46,000 | .01567 | .00067 | .00200 | .00033 | .01367 | .00034 |
| 47,000 | .01733 | .00166 | .00233 | .00033 | .01500 | .00133 |
| 48,000 | .01867 | .00134 | .00233 | .00000 | .01633 | .00133 |
| 49,000 | .01967 | .00100 | .00233 | .00000 | .01733 | .00100 |
| 50,000 | .02100 | .00133 | .00233 | .00000 | .01867 | .00134 |
| 51,000 | .02267 | .00167 | .00233 | .00000 | .02033 | .00166 |
| 52,000 | .02433 | .00166 | .00267 | .00034 | .02167 | .00134 |
| 53,000 | .02600 | .00167 | .00233 | — .00034 | .02367 | .00200 |
| 54,000 | .02733 | .00133 | .00233 | .00000 | .02500 | .00133 |
| 55,000 | .02967 | .00234 | .00267 | .00034 | .02700 | .00200 |
| 56,000 | .03133 | .00166 | .00267 | .00000 | .02867 | .00167 |
| 57,000 | .03300 | .00167 | .00267 | .00000 | .03033 | .00166 |
| 58,000 | .03533 | .00233 | .00267 | .00000 | .03267 | .00234 |
| 59,000 | .03833 | .00300 | .00300 | .00033 | .03533 | .00266 |
| 60,000 | .04067 | .00234 | .00300 | .00000 | .03767 | .00234 |
| 61,000 | .04433 | .00366 | .00300 | .00000 | .04133 | .00366 |
| 62,000 | .04733 | .00300 | .00333 | .00033 | .04400 | .00267 |
| 63,000 | .04933 | .00200 | .00333 | .00000 | .04600 | .00200 |
| 64,000 | .05367 | .00434 | .00333 | .00000 | .05033 | .00433 |
| 65,000 | .05567 | .00200 | .00333 | .00000 | .05233 | .00200 |
| 66,000 | .06133 | .00566 | .00333 | .00000 | .05800 | .00567 |
| 67,000 | .06567 | .00434 | .00333 | .00000 | .06233 | .00433 |
| 68,000 | .07100 | .00533 | .00333 | .00000 | .06767 | .00534 |
| 69,000 | .07767 | .00667 | .00367 | .00034 | .07400 | .00633 |
| 70,000 | .08400 | .00633 | .00333 | — .00034 | .08067 | .00667 |
| 71,000 | .09400 | .01000 | .00333 | .00000 | .09067 | .01000 |
| 72,000 | .10433 | .01033 | .00400 | .00067 | .10033 | .00966 |
| 73,000 | .11867 | .01434 | .00400 | .00000 | .11467 | .01434 |
| 74,000 | .13833 | .01966 | 0.00433 | 0.00033 | 0.13400 | 0.01933 |
| 75,000 | 0.27067 | 0.13234 | (*) | (*) | (*) | (*) |

*Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity (mean of three results) | 7.9002 |
| Tensile strength, per square inch ........ pounds.. | 75,000 |
| Elastic limit ........ pounds.. | 35,000 |
| Extension, per inch, at elastic limit ........ inch.. | 0.00200 |
| Extension, per inch, at rupture ........ inch.. | 0.27067 |
| Hardness (mean of three results) | 14.73 |
| Original area of cross-section ........ square inch.. | 0.3038 |
| Area after rupture ........ square inch.. | 0.1600 |
| Position of rupture | ½ from shoulder |
| Character of fracture | close, fibrous, with minute crystallized spots. |

**SPECIMEN I.**—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel* 3 *inches long (between shoulders) and* 0.623 *inch diameter, taken from breech-receiver No.* 1, *for* 11-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 9,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 10,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 11,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 12,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 13,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 14,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 15,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 16,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 17,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 18,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 19,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 20,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 21,000 | .00133 | .00033 | .00133 | .00033 | .00000 | .00000 |
| 22,000 | .00167 | .00034 | .00067 | — .00066 | .00100 | .00100 |
| 23,000 | .00267 | .00100 | .00067 | .00000 | .00200 | .00100 |
| 24,000 | .00333 | .00066 | .00100 | .00033 | .00233 | .00033 |
| 25,000 | .00400 | .00067 | .00100 | .00000 | .00300 | .00067 |
| 26,000 | .00433 | .00033 | .00100 | .00000 | .00333 | .00033 |
| 27,000 | .00567 | .00134 | .00100 | .00000 | .00467 | .00134 |
| 28,000 | .00633 | .00066 | .00133 | .00033 | .00500 | .00033 |
| 29,000 | .00667 | .00034 | .00100 | .00033 | .00567 | .00067 |
| 30,000 | .00733 | .00066 | .00133 | .00033 | .00600 | .00033 |
| 31,000 | .00800 | .00067 | .00133 | .00000 | .00667 | .00067 |
| 32,000 | .00900 | .00100 | .00100 | — .00033 | .00800 | .00133 |
| 33,000 | .01167 | .00267 | .00133 | .00033 | .01033 | .00233 |
| 34,000 | .01233 | .00066 | .00167 | .00034 | .01067 | .00034 |
| 35,000 | .01300 | .00067 | .00167 | .00000 | .01133 | .00066 |
| 36,000 | .01600 | .00300 | .00167 | .00000 | .01433 | .00300 |
| 37,000 | .01633 | .00033 | .00167 | .00000 | .01467 | .00034 |
| 38,000 | .01800 | .00167 | .00200 | .00033 | .01600 | 00133 |
| 39,000 | .01900 | .00100 | .00167 | .00033 | .01733 | 00133 |
| 40,000 | .02100 | .00200 | .00200 | .00033 | .01900 | 00167 |
| 41,000 | .02167 | .00067 | .00200 | .00000 | .01967 | .00067 |
| 42,000 | .02433 | .00266 | .00200 | .00000 | .02233 | 00266 |
| 43,000 | .02767 | .00334 | .00200 | .00000 | .02567 | .00334 |
| 44,000 | .02967 | .00200 | .00233 | .00033 | .02733 | 00166 |
| 45,000 | .03167 | .00200 | .00233 | .00000 | .02933 | .00200 |
| 46,000 | .03333 | .00166 | .00200 | — .00033 | .03133 | .00200 |
| 47,000 | .03600 | .00267 | .00200 | .00000 | .03400 | .00267 |
| 48,000 | .03833 | .00233 | .00267 | .00067 | .03567 | .00167 |
| 49,000 | .04267 | .00434 | .00267 | .00000 | .04000 | .00433 |
| 50,000 | .04567 | .00300 | .00300 | .00033 | .04267 | .00267 |
| 51,000 | .04900 | .00333 | .00267 | — .00033 | .04633 | .00366 |
| 52,000 | .05500 | .00600 | .00333 | .00066 | .05167 | .00534 |
| 53,000 | .05833 | .00333 | .00300 | — .00033 | .05533 | .00366 |
| 54,000 | .06500 | .00667 | .00367 | .00067 | .06133 | .00600 |
| 55,000 | .07067 | .00567 | .00333 | — .00034 | .06733 | .00600 |
| 56,000 | .07767 | .00700 | .00367 | .00034 | .07400 | .00667 |
| 57,000 | .08800 | .01033 | .00367 | .00000 | .08433 | .01033 |
| 58,000 | .09569 | .00767 | .00367 | .00000 | .09200 | .00767 |
| 59,000 | .10867 | .01300 | .00400 | .00033 | .10467 | .01267 |
| 60,000 | .12900 | .02033 | .00400 | .00000 | .12500 | .02033 |
| 61,000 | .15600 | .02700 | 0.00467 | .00067 | 0.15133 | 0.02633 |
| 62,000 | 0.22400 | 0.06800 | (*) | (*) | (*) | (*) |

* Specimen broke.

GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7.8775 |
| Tensile strength, per square inch ......pounds.. | 62,000 |
| Elastic limit ......pounds.. | 22,000 |
| Extension, per inch, at elastic limit ......inch.. | 0.00167 |
| Extension, per inch, at rupture ......inch.. | 0.22400 |
| Hardness | 9.313 |
| Original area of cross-section ......square inch.. | 0.3048 |
| Area after rupture ......square inch.. | 0.1698 |
| Position of rupture | ½ from shoulder. |
| Character of fracture ......coarse, fibrous, with occasional granular spots. | |

SPECIMEN II.—*Table showing the extension, restoration, and permanent set, per inch in length caused by the undermentioned weights, per square inch of section, acting on a solid cylinder, of steel* 3 *inches long (between shoulders) and* 0.623 *inch diameter, taken from breech-receiver No.* 1, *for* 11-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 9,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 10,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 11,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 12,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 13,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 15,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 16,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 17,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 18,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 19,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 20,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 21,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 22,000 | .00133 | .00100 | .00100 | .00067 | .00033 | .00033 |
| 23,000 | .00167 | .00034 | .00133 | .00033 | .00033 | .00000 |
| 24,000 | .00167 | .00000 | .00133 | .00000 | .00033 | .00000 |
| 25,000 | .00233 | .00066 | .00067 | —.00066 | .00167 | .00134 |
| 26,000 | .00300 | .00067 | .00100 | .00033 | .00200 | .00033 |
| 27,000 | .00367 | .00067 | .00067 | —.00033 | .00300 | .00100 |
| 28,000 | .00467 | .00100 | .00133 | .00066 | .00333 | .00033 |
| 29,000 | .00567 | .00100 | .00133 | .00000 | .00433 | .00100 |
| 30,000 | .00700 | .00133 | .00133 | .00000 | .00567 | .00134 |
| 31,000 | .00767 | .00067 | .00100 | —.00033 | .00667 | .09100 |
| 32,000 | .01000 | .00233 | .00233 | .00133 | .00767 | .00100 |
| 33,000 | .01200 | .00200 | .00133 | —.00100 | .01067 | .00300 |
| 34,000 | .01300 | .00100 | .00167 | .00034 | .01133 | .00066 |
| 35,000 | .01367 | .00067 | .00167 | .00000 | .01200 | .00067 |
| 36,000 | .01500 | .00133 | .00200 | .00033 | .01300 | .00100 |
| 37,000 | .01600 | .00100 | .00167 | —.00033 | .01433 | .00133 |
| 38,000 | .01767 | .00167 | .00200 | .00033 | .01567 | .00134 |
| 39,000 | .01900 | .00133 | .00200 | .00000 | .01700 | .00133 |
| 40,000 | .02100 | .00200 | .00200 | .00000 | .01900 | .00200 |
| 41,000 | .02300 | .00200 | .00167 | —.00033 | .02133 | .00233 |
| 42,000 | .02500 | .00200 | .00200 | .00033 | .02300 | .00167 |
| 43,000 | .02700 | .00200 | .00200 | .00000 | .02500 | .00200 |
| 44,000 | .02967 | .00267 | .00200 | .00000 | .02767 | .00267 |
| 45,000 | .03200 | .00233 | .00200 | .00000 | .03000 | .00233 |
| 46,000 | .03467 | .00267 | .00100 | —.00100 | .03367 | .00367 |
| 47,000 | .03700 | .00233 | .00200 | .00100 | .03500 | .00133 |
| 48,000 | .04033 | .00333 | .00233 | .00033 | .03800 | .00300 |
| 49,000 | .04400 | .00367 | .00267 | .00034 | .04133 | .00333 |
| 50,000 | .04733 | .00333 | .00233 | —.00034 | .04500 | .00367 |
| 51,000 | 0.05200 | 0.00467 | 0.00267 | 0.00034 | 0.04933 | 0.00433 |

### GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7.8816 |
| Tensile strength, per square inch ... pounds.. | 51,000 |
| Elastic limit ... pounds.. | 22,000 |
| Extension, per inch, at elastic limit ... inch.. | 0.00133 |
| Extension, per inch, at rupture ... inch.. | 0.05200 |
| Hardness | 9.718 |
| Original area of cross-section ... square inch.. | 0.3048 |
| Area after rupture ... square inch.. | 0.2861 |
| Position of rupture | ¼ from shoulder. |
| Character of fracture | granular. |

SPECIMEN III.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel, 3 inches long (between shoulders) and 0.623 inch diameter, taken from breech-receiver No. 1, for 11-inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 9,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 10,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 11,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 12,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 13,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 14,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 15,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 16,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 17,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 18,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 19,000 | .00267 | .00200 | .00100 | .00033 | .00167 | .00167 |
| 20,000 | .00333 | .00066 | .00100 | .00000 | .00233 | .00066 |
| 21,000 | .00367 | .00034 | .00100 | .00000 | .00267 | .00034 |
| 22,000 | .00367 | .00000 | .00100 | .00000 | .00267 | .00000 |
| 23,000 | .00400 | .00033 | .00100 | .00000 | .00300 | .00033 |
| 24,000 | .00433 | .00033 | .00067 | —.00033 | .00367 | .00067 |
| 25,000 | .00500 | .00067 | .00100 | .00033 | .00400 | .00033 |
| 26,000 | .00633 | .00133 | .00133 | .00033 | .00500 | .00100 |
| 27,000 | .00767 | .00134 | .00133 | .00000 | .00633 | .00133 |
| 28,000 | .00967 | .00200 | .00100 | —.00033 | .00867 | .00234 |
| 29,000 | .01000 | .00033 | .00100 | .00000 | .00900 | .00033 |
| 30,000 | .01067 | .00067 | .00133 | .00033 | .00933 | .00033 |
| 31,090 | .01167 | .00100 | .00167 | .00034 | .01000 | .00067 |
| 32,000 | .01267 | .00100 | .00133 | —.00034 | .01133 | .00133 |
| 33,000 | .01433 | .00166 | .00167 | .00034 | .01267 | .00134 |
| 34,000 | .01600 | .00167 | .00133 | —.00034 | .01467 | .00200 |
| 35,000 | .01733 | .00133 | .00133 | .00000 | .01600 | .00133 |
| 36,000 | .01900 | .00167 | .00133 | .00000 | .01767 | .00167 |
| 37,000 | .02033 | .00133 | .00167 | .00034 | .01867 | .00100 |
| 38,000 | .02233 | .00200 | .00167 | .00000 | .02067 | .00200 |
| 39,000 | .02433 | .00200 | .00133 | —.00034 | .02300 | .00233 |
| 40,000 | .02600 | .00167 | .00167 | .00034 | .02433 | .00133 |
| 41,000 | .02767 | .00167 | .00167 | .00000 | .02600 | .00167 |
| 42,000 | .03000 | .00233 | .00200 | .00033 | .02800 | .00200 |
| 43,000 | .03200 | .00200 | .00133 | —.00067 | .03067 | .00267 |
| 44,000 | .03467 | .00267 | .00200 | .00067 | .03267 | .00200 |
| 45,000 | .03733 | .00266 | .00167 | —.00033 | .03567 | .00300 |
| 46,000 | .04067 | .00334 | .00167 | .00000 | .03900 | .00333 |
| 47,000 | .04367 | .00300 | .00200 | .00033 | .04167 | .00267 |
| 48,000 | .04733 | .00366 | .00267 | .00067 | .04467 | .00300 |
| 49,000 | .05183 | .00400 | .00200 | —.00067 | .04933 | .00466 |
| 50,000 | .05467 | .00334 | .00200 | .00000 | .05267 | .00334 |
| 51,000 | .06033 | .00566 | .00233 | .00033 | .05800 | .00533 |
| 52,000 | .06600 | .00567 | .00200 | —.00033 | .06400 | .00600 |
| 53,000 | .07067 | .00467 | .00233 | .00033 | .06833 | .00433 |

SPECIMEN III.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 54, 000 | 0. 07800 | 0. 00733 | 0. 00267 | 0. 00034 | 0. 07533 | 0. 00700 |
| 55, 000 | . 08500 | . 00700 | . 00300 | . 00033 | . 08200 | . 00667 |
| 56, 000 | . 09567 | . 01067 | . 00300 | . 00000 | . 09267 | . 01067 |
| 57, 000 | . 10633 | . 01066 | . 00300 | . 00000 | . 10333 | . 01066 |
| 58, 000 | . 12400 | . 01767 | . 00333 | . 00033 | . 12067 | . 01734 |
| 59, 000 | . 14100 | . 01700 | . 00333 | . 00000 | . 13767 | . 01700 |
| 60, 000 | . 18067 | . 03967 | 0. 00400 | 0. 00067 | 0. 17667 | 0. 03900 |
| 61, 000 | 0. 29067 | 0. 11000 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7. 8746 |
| Tensile strength, per square inch ........ pounds.. | 61, 000 |
| Elastic limit ........ pounds.. | 19, 000 |
| Extension, per inch, at elastic limit ........ inch.. | 0. 00267 |
| Extension, per inch, at rupture ........ inch.. | 0. 29067 |
| Hardness | 9. 929 |
| Original area of cross-section ........ square inch.. | 0. 3048 |
| Area after rupture ........ square inch.. | 0. 1757 |
| Position of rupture | ½ from shoulder. |
| Character of fracture | coarse, fibrous, with granular spots. |

SPECIMEN V.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel* 3 *inches long (between shoulders) and* 0.625 *inch diameter, taken from breech-receiver No.* 1, *for* 11-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00033 | . 00033 | . 00033 | . 00033 | . 00000 | . 00000 |
| 4, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 5, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 6, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 7, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 8, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 9, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 10, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 11, 000 | . 00067 | . 00034 | . 00067 | . 00034 | . 00000 | . 00000 |
| 12, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 13, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 14, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 15, 000 | . 00100 | . 00033 | . 00100 | . 00033 | . 00000 | . 00000 |
| 16, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 17, 000 | . 00200 | . 00100 | . 00067 | —. 00033 | . 00133 | . 00133 |
| 18, 000 | . 00233 | . 00033 | . 00067 | . 00000 | . 00167 | . 00034 |
| 19, 000 | . 00300 | . 00067 | . 00067 | . 00000 | . 00233 | . 00066 |
| 20, 000 | . 00333 | . 00033 | . 00067 | . 00000 | . 00267 | . 00034 |
| 21, 000 | . 00433 | . 00100 | . 00100 | . 00033 | . 00333 | . 00066 |
| 22, 000 | . 00500 | . 00067 | . 00100 | . 00000 | . 00400 | . 00067 |
| 23, 000 | . 00600 | . 00100 | . 00133 | . 00033 | . 00467 | . 00067 |
| 24, 000 | . 00700 | . 00100 | . 00100 | —. 00033 | . 00600 | . 00133 |
| 25, 000 | . 00833 | . 00133 | . 00133 | . 00033 | . 00700 | . 00100 |
| 26, 000 | . 00933 | . 00100 | . 00133 | . 00000 | . 00800 | . 00100 |
| 27, 000 | . 01067 | . 00134 | . 00133 | . 00000 | . 00933 | . 00133 |

**Specimen V.**—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 028, 000 | 0. 01233 | 0. 00166 | 0. 00133 | 0. 00000 | 0. 01100 | 0. 00167 |
| 29, 000 | . 01333 | . 00100 | . 00133 | . 00000 | . 01200 | . 00100 |
| 30, 000 | . 01467 | . 00134 | . 00167 | . 00034 | . 01300 | . 00100 |
| 31, 000 | . 01600 | . 00133 | . 00167 | . 00000 | . 01433 | . 00133 |
| 32, 000 | . 01733 | . 00133 | . 00167 | . 00000 | . 01567 | . 00134 |
| 33, 000 | . 01900 | . 00167 | . 00167 | . 00000 | . 01733 | . 00166 |
| 34, 000 | . 02033 | . 00133 | . 00133 | — . 00034 | . 01900 | . 00167 |
| 35, 000 | . 02233 | . 00200 | . 00167 | . 00034 | . 02067 | . 00167 |
| 36, 000 | . 02467 | . 00234 | . 00167 | . 00000 | . 02300 | . 00233 |
| 37, 000 | . 02633 | . 00166 | . 00167 | . 00000 | . 02467 | . 00167 |
| 38, 000 | . 02800 | . 00167 | . 00167 | . 00000 | . 02633 | . 00166 |
| 39, 000 | . 03100 | . 00300 | . 00233 | . 00066 | . 02867 | . 00234 |
| 40, 000 | . 03300 | . 00200 | . 00233 | . 00000 | . 03067 | . 00200 |
| 41, 000 | . 03500 | . 00200 | . 00200 | . 00033 | . 03300 | . 00233 |
| 42, 000 | . 03733 | . 00233 | . 00200 | . 00000 | . 03533 | . 00233 |
| 43, 000 | . 04033 | . 00300 | . 00267 | . 00067 | . 03767 | . 00234 |
| 44, 000 | . 04333 | . 00300 | . 00200 | . 00067 | . 04133 | . 00366 |
| 45, 000 | . 04600 | . 00267 | . 00200 | . 00000 | . 04400 | . 00267 |
| 46, 000 | . 04967 | . 00367 | . 00233 | . 00033 | . 04733 | . 00333 |
| 47, 000 | . 05267 | . 00300 | . 00233 | . 00000 | . 05033 | . 00300 |
| 48, 000 | . 05933 | . 00666 | . 00267 | . 00034 | . 05667 | . 00634 |
| 49, 000 | . 06200 | . 00267 | . 00233 | — . 00034 | . 05967 | . 00300 |
| 50, 000 | . 06667 | . 00467 | . 00267 | . 00034 | . 06400 | . 00433 |
| 51, 000 | . 07467 | . 00800 | . 00300 | . 00033 | . 07167 | . 00767 |
| 52, 000 | . 07900 | . 00567 | . 00267 | — . 00033 | . 07633 | . 00466 |
| 53, 000 | . 08833 | . 00933 | . 00267 | . 00000 | . 08567 | . 00934 |
| 54, 000 | . 09767 | . 00934 | . 00333 | . 00066 | . 09433 | . 00866 |
| 55, 000 | . 10867 | . 01100 | . 00367 | . 00034 | . 10500 | . 01067 |
| 56, 000 | . 12500 | . 01633 | . 00333 | — . 00034 | . 12167 | . 01667 |
| 57, 000 | . 14467 | . 01967 | . 00367 | . 00034 | . 14100 | . 01933 |
| 58, 000 | . 19300 | . 08733 | 0. 00400 | 0. 00033 | 0. 18900 | 0. 04800 |
| 59, 000 | 0. 28433 | 0. 09133 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7. 8889 |
| Tensile strength, per square inch ............ pounds.. | 59, 000 |
| Elastic limit ............ pounds.. | 17. 000 |
| Extension, per inch, at elastic limit ............ inch.. | 0. 00200 |
| Extension, per inch, at rupture ............ inch.. | 0. 28433 |
| Hardness | 9. 138 |
| Original area of cross-section ............ square inch.. | 0. 3067 |
| Area after rupture ............ square inch.. | 0. 1832 |
| Position of rupture ............ | ¼ from shoulder |
| Character of fracture ............ | light gray, crystalline predominating |

**Specimen VI.**—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel* 3 *inches long* (*between shoulders*) *and* 0.623 *inch diameter, taken from breech-receiver No.* 1, *for* 11-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 4, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |

SPECIMEN VI.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 5,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 8,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 9,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 10,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 11,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 12,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 13,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 14,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 15,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 16,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 17,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 18,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 19,000 | .00100 | .00000 | .00067 | —.00033 | .00033 | .00033 |
| 20,000 | .00167 | .00067 | .00067 | .00000 | .00100 | .00067 |
| 21,000 | .00300 | .00133 | .00100 | .00033 | .00200 | .00100 |
| 22,000 | .00400 | .00100 | .00067 | —.00033 | .00333 | .00133 |
| 23,000 | .00633 | .00233 | .00100 | .00033 | .00533 | .00200 |
| 24,000 | .00667 | .00034 | .00100 | .00000 | .00567 | .00034 |
| 25,000 | .00700 | .00033 | .00100 | .00000 | .00600 | .00033 |
| 26,000 | .00800 | .00100 | .00100 | .00000 | .00700 | .00100 |
| 27,000 | .00933 | .00133 | .00100 | .00000 | .00833 | .00133 |
| 28,000 | .01033 | .00100 | .00100 | .00000 | .00933 | .00100 |
| 29,000 | .01167 | .00134 | .00100 | .00000 | .01067 | .00134 |
| 30,000 | .01300 | .00133 | .00133 | .00033 | .01167 | .00100 |
| 31,000 | .01433 | .00133 | .00133 | .00000 | .01300 | .00133 |
| 32,000 | .01533 | .00100 | .00167 | .00034 | .01367 | .00067 |
| 33,000 | .01667 | .00134 | .00167 | .00000 | .01500 | .00133 |
| 34,000 | .01800 | .00133 | .00167 | .00000 | .01633 | .00133 |
| 35,000 | .01967 | .00167 | .00167 | .00000 | .01800 | .00167 |
| 36,000 | .02167 | .00200 | .00167 | .00000 | .02000 | .00200 |
| 37,000 | .02300 | .00133 | .00200 | .00033 | .02100 | .00100 |
| 38,000 | .02467 | .00167 | .00200 | .00000 | .02267 | .00167 |
| 39,000 | .02633 | .00166 | .00200 | .00000 | .02433 | .00166 |
| 40,000 | .02867 | .00234 | .00167 | —.00033 | .02700 | .00267 |
| 41,000 | .03100 | .00233 | .00200 | .00033 | .02900 | .00200 |
| 42,000 | .03300 | .00200 | .00200 | .00000 | .03100 | .00200 |
| 43,000 | .03667 | .00367 | .00200 | .00000 | .03467 | .00367 |
| 44,000 | .03867 | .00200 | .00233 | .00033 | .03633 | .00166 |
| 45,000 | .04133 | .00266 | .00233 | .00000 | .03900 | .00267 |
| 46,000 | .04500 | .00367 | .00233 | .00000 | .04267 | .00367 |
| 47,000 | .04800 | .00300 | .00300 | .00067 | .04500 | .00233 |
| 48,000 | .05200 | .00400 | .00233 | —.00067 | .04967 | .00467 |
| 49,000 | .05600 | .00400 | .00267 | .00034 | .05333 | .00366 |
| 50,000 | .06200 | .00600 | .00267 | .00000 | .05933 | .00600 |
| 51,000 | .06600 | .00400 | .00267 | .00000 | .06333 | .00400 |
| 52,000 | .07300 | .00700 | .00267 | .00000 | .07033 | .00700 |
| 53,000 | .07900 | .00600 | .00267 | .00000 | .07633 | .00600 |
| 54,000 | .08667 | .00767 | .00267 | .00000 | .08400 | .00767 |
| 55,000 | .09933 | .01266 | .00300 | .00033 | .09633 | .01233 |
| 56,000 | .10867 | .00934 | .00300 | .00000 | .10567 | .00934 |
| 57,000 | .12433 | .01566 | .00333 | .00033 | .12100 | .01533 |
| 58,000 | .14367 | .01934 | .00333 | .00000 | .14033 | .01933 |
| 59,000 | .18567 | .04200 | 0.00367 | 0.00034 | 0.18200 | 0.04167 |
| 60,000 | 0.30933 | 0.12366 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7.92150 |
| Tensile strength, per square inch ... pounds.. | 60,000 |
| Elastic limit ... pounds.. | 19,000 |
| Extension, per inch, at elastic limit ... inch.. | 0.0010 |
| Extension, per inch, at rupture ... inch.. | 0.30933 |
| Hardness | 9.3133 |
| Original area of cross-section ... square inch.. | 0.3048 |
| Area after rupture ... square inch.. | 0.1720 |
| Position of rupture | ½ from shoulder. |
| Character of fracture | medium gray, mixed, fibrous, and crystalline. |

SPECIMEN I.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel, 3 inches long (between shoulders) and 0.623 inches diameter, taken from breech-receiver No. 2, for 11-inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 9,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 10,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 11,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 12,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 13,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 14,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 15,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 16,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 17,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 18,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 19,000 | .00133 | .00033 | .00067 | —.00033 | .00067 | .00067 |
| 20,000 | .00233 | .00100 | .00067 | .00000 | .00167 | .00100 |
| 21,000 | .00300 | .00067 | .00100 | .00033 | .00200 | .00033 |
| 22,000 | .00367 | .00067 | .00100 | .00000 | .00267 | .00067 |
| 23,000 | .00467 | .00100 | .00100 | .00000 | .00367 | .00100 |
| 24,000 | .00533 | .00066 | .00100 | .00000 | .00433 | .00066 |
| 25,000 | .00600 | .00067 | .00100 | .00000 | .00500 | .00067 |
| 26,000 | .00800 | .00200 | .00100 | .00000 | .00700 | .00200 |
| 27,000 | .01033 | .00233 | .00133 | .00033 | .00900 | .00200 |
| 28,000 | .01100 | .00067 | .00133 | .00000 | .00967 | .00067 |
| 29,000 | .01133 | .00033 | .00133 | .00000 | .01000 | .00033 |
| 30,000 | .01200 | .00067 | .00133 | .00000 | .01067 | .00067 |
| 31,000 | .01267 | .00067 | .00133 | .00000 | .01133 | .00066 |
| 32,000 | .01400 | .00133 | .00133 | .00000 | .01267 | .00134 |
| 33,000 | .01500 | 00100 | .00133 | .00000 | .01367 | .00100 |
| 34,000 | .01733 | .00233 | .00167 | .00034 | .01567 | .00200 |
| 35,000 | .01867 | .00134 | .00167 | .00000 | .01700 | .00133 |
| 36,000 | .02033 | .00166 | .00200 | .00033 | .01833 | .00133 |
| 37,000 | .02167 | .00134 | .00200 | .00000 | .01967 | .00134 |
| 38,000 | .02333 | .00166 | .00200 | .00000 | .02133 | .00166 |
| 39,000 | .02467 | .00134 | .00167 | —.00033 | .02300 | .00167 |
| 40,000 | .02700 | .00233 | .00200 | .00033 | .02500 | .00200 |
| 41,000 | .02967 | .00267 | .00233 | .00033 | .02733 | .00233 |
| 42,000 | .03100 | .00133 | .00200 | —.00033 | .02900 | .00167 |
| 43,000 | .03300 | .00200 | .00233 | .00033 | .03067 | .00167 |
| 44,000 | .03567 | .00267 | .00267 | .00034 | .03300 | .00233 |
| 45,000 | .03800 | .00233 | .00233 | —.00034 | .03567 | .00267 |
| 46,000 | .04033 | .00233 | .00233 | .00000 | .03800 | .00233 |
| 47,000 | .04500 | .00467 | .00233 | .00000 | .04267 | .00467 |
| 48,000 | .04967 | .00467 | .00233 | .00000 | .04733 | .00466 |
| 49,000 | .05167 | .00200 | .00267 | .00034 | .04900 | .00167 |
| 50,000 | .05467 | .00300 | .00267 | .00000 | .05200 | .00300 |
| 51,000 | .05833 | .00366 | .00233 | —.00034 | .05600 | .00400 |
| 52,000 | .06467 | .00634 | .00267 | .00034 | .06200 | .00600 |
| 53,000 | .06900 | .00433 | .00333 | .00066 | .06567 | .00367 |
| 54,000 | .07433 | .00533 | .00267 | —.00066 | .07167 | .00600 |
| 55,000 | .08233 | .00800 | .00333 | .00066 | .07900 | .00733 |
| 56,000 | .09400 | .01167 | .00333 | .00000 | .09067 | .01167 |
| 57,000 | .10067 | .00667 | .00333 | .00000 | .09733 | .00666 |
| 58,000 | .11000 | .00933 | .00367 | .00034 | .10633 | .00900 |
| 59,000 | .12467 | .01467 | .00300 | —.00067 | .12167 | .01534 |
| 60,000 | .14233 | .01766 | .00367 | .00067 | .13867 | .01700 |
| 61,000 | .17467 | .03234 | 0.00400 | 0.00033 | 0.17067 | 0.[illegible] |
| 62,000 | 0.26833 | 0.09366 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | | |
|---|---|---|
| Specific gravity | | |
| Tensile strength, per square inch | pounds.. | 62, 000 |
| Elastic limit | pounds.. | 19, 000 |
| Extension, per inch, at elastic limit | inch.. | 0. 00133 |
| Extension, per inch, at rupture | inch.. | 0. 26833 |
| Hardness | | |
| Original area of cross-section | square inch.. | 0. 3048 |
| Area after rupture | square inch.. | 0. 1698 |
| Position of rupture | | One-fourth from shoulder. |
| Character of fracture | | Close fibrous. |

SPECIMEN II.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the under-mentioned weights, per square inch of section, acting on a solid cylinder of steel,* 3 *inches long (between shoulders) and* 0.450 *inch diameter, taken from breech-receiver No.* 2, *for* 11-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 4, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 5, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 6, 000 | . 00033 | . 00033 | . 00033 | . 00033 | . 00000 | . 00000 |
| 7, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 8, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 9, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 10, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 11, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 12, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 13, 000 | . 00067 | . 00034 | . 00067 | . 00034 | . 00000 | . 00000 |
| 14, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 15, 000 | . 00100 | . 00033 | . 00100 | . 00033 | . 00000 | . 00000 |
| 16, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 17, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 18, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 19, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 20, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 21, 000 | . 00100 | . 00000 | . 00100 | . 00000 | . 00000 | . 00000 |
| 22, 000 | . 00133 | . 00033 | . 00067 | —. 00033 | . 00067 | . 00067 |
| 23, 000 | . 00333 | . 00200 | . 00100 | . 00033 | . 00233 | . 00166 |
| 24, 000 | . 00467 | . 00134 | . 00067 | —. 00033 | . 00400 | . 00167 |
| 25, 000 | . 00633 | . 00166 | . 00100 | . 00033 | . 00533 | . 00133 |
| 26, 000 | . 00800 | . 00167 | . 00167 | . 00067 | . 00633 | . 00100 |
| 27, 000 | . 00867 | . 00167 | . 00133 | —. 00034 | . 00733 | . 00100 |
| 28, 000 | . 01033 | . 00166 | . 00167 | . 00034 | . 00867 | . 00134 |
| 29, 000 | . 01133 | . 00100 | . 00167 | . 00000 | . 00967 | . 00100 |
| 30, 000 | . 01167 | . 00034 | . 00133 | —. 00034 | . 01033 | . 00066 |
| 31, 000 | . 01300 | 00133 | . 00133 | . 00000 | . 01167 | . 00134 |
| 32, 000 | . 01400 | . 00100 | . 00133 | . 00000 | . 01267 | . 00100 |
| 33, 000 | . 01533 | . 00133 | . 00133 | . 00000 | . 01400 | . 00133 |
| 34, 000 | . 01600 | . 00067 | . 00133 | . 00000 | . 01467 | . 00067 |
| 35, 000 | . 01833 | . 00233 | . 00167 | . 00034 | . 01667 | . 00200 |
| 36, 000 | . 01967 | . 00134 | . 00167 | . 00000 | . 01800 | . 00133 |
| 37, 000 | . 02133 | . 00166 | . 00167 | . 00000 | . 01967 | . 00167 |
| 38, 000 | . 02300 | . 00167 | . 00167 | . 00000 | . 02133 | . 00166 |
| 39, 000 | . 02467 | . 00167 | . 00167 | . 00000 | . 02300 | . 00167 |
| 40, 000 | . 02667 | . 00200 | . 00200 | . 00033 | . 02467 | . 00167 |
| 41, 000 | . 02900 | . 00233 | . 00200 | . 00000 | . 02700 | . 00233 |
| 42, 000 | . 03100 | . 00200 | . 00200 | . 00000 | . 02900 | . 00200 |
| 43, 000 | . 03333 | . 00233 | . 00200 | . 00000 | . 03133 | . 00233 |
| 44, 000 | . 03533 | . 00200 | . 00167 | —. 00033 | . 03367 | . 00234 |
| 45, 000 | . 03767 | . 00234 | . 00200 | . 00033 | . 03567 | . 00200 |
| 46, 000 | . 04033 | . 00266 | . 00233 | . 00033 | . 03800 | . 00233 |
| 47, 000 | . 04633 | . 00600 | . 00233 | . 00000 | . 04400 | . 00600 |
| 48, 000 | . 04833 | . 00200 | . 00267 | . 00034 | . 04567 | . 00167 |
| 49, 000 | . 05100 | . 00267 | . 00267 | . 00000 | . 04833 | . 00266 |
| 50, 000 | . 05333 | . 00233 | . 00233 | —. 00034 | . 05100 | . 00267 |
| 51, 000 | . 05833 | . 00500 | . 00267 | . 00034 | . 05567 | . 00467 |
| 52, 000 | . 06233 | . 00400 | . 00200 | —. 00067 | . 06033 | . 00466 |
| 53, 000 | . 06833 | . 00600 | . 00267 | . 00067 | . 06567 | . 00534 |
| 54, 000 | . 07433 | . 00600 | . 00333 | . 00066 | . 07100 | . 00533 |
| 55, 000 | . 08067 | . 00634 | . 00300 | —. 00033 | . 07767 | . 00667 |
| 56, 000 | . 08933 | 0. 00866 | 0. 00233 | —. 00067 | 0. 08700 | 0. 00933 |

SPECIMEN II.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 057, 000 | 0. 09867 | 0. 00934 | 0. 00300 | 0. 00067 | 0. 09567 | 0. 00867 |
| 58, 000 | . 11100 | . 01233 | . 00333 | . 00033 | . 10767 | . 01200 |
| 59, 000 | . 12667 | . 01565 | . 00400 | . 00067 | . 12267 | . 01500 |
| 60, 000 | . 14700 | . 02033 | . 00333 | —. 00067 | . 14367 | . 02100 |
| 61, 000 | . 19100 | . 04400 | 0. 00400 | 0. 00067 | 0. 18700 | 0. 04333 |
| 62, 000 | 0. 28933 | 0. 09833 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

Specific gravity ........................................

Tensile strength, per square inch ........................................pounds.. 62, 000

Elastic limit ........................................pounds.. 22, 000

Extension, per inch, at elastic limit ........................................inch.. 0. 00133

Extension, per inch, at rupture ........................................inch.. 0. 28933

Hardness ........................................

Original area of cross-section ........................................square inch.. 0. 3038

Area after rupture ........................................square inch.. 0. 1596

Position of rupture........................................Near middle.

Character of fracture ........................................Close fibrous.

SPECIMEN III.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel,* 3 *inches long (between shoulders) and* 0.622 *inch diameter, taken from breech-receiver No.* 2, *for* 11-*inch breech-loading rifle.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1, 000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 | 0. 00000 |
| 2, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 3, 000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 | . 00000 |
| 4, 000 | . 00033 | . 00033 | . 00033 | . 00033 | . 00000 | . 00000 |
| 5, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 6, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 7, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 8, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 9. 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 10, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 11, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 12, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 13, 000 | . 00033 | . 00000 | . 00033 | . 00000 | 00000 | . 00000 |
| 14, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 15, 000 | . 00033 | . 00000 | . 00033 | . 00000 | . 00000 | . 00000 |
| 16, 000 | . 00067 | . 00034 | . 00067 | . 00034 | . 00000 | . 00000 |
| 17, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 18, 000 | . 00067 | . 00000 | . 00067 | . 00000 | . 00000 | . 00000 |
| 19, 000 | . 00133 | . 00066 | . 00100 | . 00033 | . 00033 | . 00033 |
| 20, 000 | . 00233 | . 00100 | . 00100 | . 00000 | . 00133 | . 00100 |
| 21, 000 | . 00300 | . 00067 | . 00100 | . 00000 | . 00200 | . 00067 |
| 22, 000 | . 00400 | . 00100 | . 00100 | . 00000 | . 00300 | . 00100 |
| 23, 000 | . 00467 | . 00067 | . 00100 | . 00000 | . 00367 | . 00067 |
| 24, 000 | . 00533 | . 00066 | . 00100 | . 00000 | . 00433 | . 00066 |
| 25, 000 | . 00633 | . 00100 | . 00133 | . 00033 | . 00500 | . 00067 |
| 26, 000 | . 00700 | . 00067 | . 00133 | . 00000 | . 00567 | . 00067 |
| 27, 000 | . 00767 | . 00067 | . 00133 | . 00000 | . 00633 | . 00066 |
| 28, 000 | . 00900 | . 00133 | . 00100 | — . 00033 | . 00800 | . 00167 |

SPECIMEN III.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 29, 000 | 0. 00967 | 0. 00067 | 0. 00100 | 0. 00000 | 0. 00867 | 0. 00067 |
| 30, 000 | . 01067 | . 00100 | . 00133 | . 00033 | . 00933 | . 00066 |
| 31, 000 | . 01200 | . 00133 | . 00133 | . 00000 | . 01067 | . 00134 |
| 32, 000 | . 01300 | . 00100 | . 00167 | . 00034 | . 01133 | . 00066 |
| 33, 000 | . 01433 | . 00133 | . 00167 | . 00000 | . 01267 | . 00134 |
| 34, 000 | . 01567 | . 00134 | . 00133 | — . 00034 | . 01433 | . 00166 |
| 35, 000 | . 01700 | . 00133 | . 00133 | . 00000 | . 01567 | . 00134 |
| 36, 000 | . 01800 | . 00100 | . 00133 | . 00000 | . 01667 | . 00100 |
| 37, 000 | . 01967 | . 00167 | . 00133 | . 00000 | . 01833 | . 00166 |
| 38, 000 | . 02133 | . 00166 | . 00167 | . 00034 | . 01967 | . 00134 |
| 39, 000 | . 02433 | . 00300 | . 00167 | . 00000 | . 02267 | . 00300 |
| 40, 000 | . 02567 | . 00134 | . 00167 | . 00000 | . 02400 | . 00133 |
| 41, 000 | . 02733 | . 00166 | . 00167 | . 00000 | . 02567 | . 00167 |
| 42, 000 | . 02867 | . 00134 | . 00167 | . 00000 | . 02700 | . 00133 |
| 43, 000 | . 03033 | . 00166 | . 00200 | . 00033 | . 02833 | . 00133 |
| 44, 000 | . 03300 | . 00267 | . 00233 | . 00033 | . 03067 | . 00234 |
| 45, 000 | . 03433 | . 00133 | . 00200 | — . 00033 | . 03233 | . 00166 |
| 46, 000 | . 03900 | . 00467 | . 00233 | . 00033 | . 03667 | . 00434 |
| 47, 000 | . 04167 | . 00267 | . 00233 | . 00000 | . 03933 | . 00266 |
| 48, 000 | . 04367 | . 00200 | . 00233 | . 00000 | . 04133 | . 00200 |
| 49, 000 | . 04700 | . 00333 | . 00267 | . 00034 | . 04433 | . 00300 |
| 50, 000 | . 05100 | . 00400 | . 00200 | — . 00067 | . 04900 | . 00467 |
| 51, 000 | . 05533 | . 00433 | . 00300 | . 00100 | . 05233 | . 00333 |
| 52, 000 | . 06067 | . 00534 | . 00233 | — . 00067 | . 05833 | . 00600 |
| 53, 000 | . 06667 | . 00600 | . 00300 | . 00067 | . 06367 | . 00534 |
| 54, 000 | . 06867 | . 00200 | . 00233 | — . 00067 | . 06633 | . 00266 |
| 55, 000 | . 07867 | . 01000 | . 00300 | . 00067 | . 07567 | . 00934 |
| 56, 000 | . 08333 | . 00466 | . 00300 | . 00000 | . 08033 | . 00466 |
| 57, 000 | . 09500 | . 01167 | . 00300 | . 00000 | . 09200 | . 01167 |
| 58, 000 | . 10233 | . 00733 | . 00333 | . 00033 | . 09900 | . 00700 |
| 59, 000 | . 11800 | . 01567 | . 00333 | . 00000 | . 11467 | . 01567 |
| 60, 000 | . 13700 | . 01900 | . 00367 | . 00034 | . 13333 | . 01866 |
| 61, 000 | . 16900 | . 03200 | 0. 00400 | 0. 00033 | 0. 16500 | 0. 03167 |
| 62, 000 | 0. 30367 | 0. 13467 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

Specific gravity ....................................................................................
Tensile strength, per square inch ............................................................pounds.. 62, 000
Elastic limit .......................................................................................pounds.. 19, 000
Extension, per inch, at elastic limit ...........................................................inch.. 0. 00133
Extension, per inch, at rupture ..................................................................inch.. 0. 30367
Hardness ...............................................................................................
Original area of cross-section ...........................................................square inch.. 0. 3038
Area after rupture ..........................................................................square inch.. 0. 1611
Position of rupture ................................................................................ ½ from shoulder.
Character of fracture ..................................................................................Fibrous.

SPECIMEN I.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel, 3 inches long (between shoulders) and 0.622 inch diameter, taken from breech-receiver for 12-inch breech-loading rifled howitzer.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 7,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 8,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 9,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 10,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 11,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 12,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 13,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 14,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 15,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 16,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 17,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 18,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 19,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 20,000 | .00200 | .00100 | .00100 | .00000 | .00100 | .00100 |
| 21,000 | .00233 | .00033 | .00100 | .00000 | .00133 | .00033 |
| 22,000 | .00233 | .00000 | .00100 | .00000 | .00133 | .00000 |
| 23,000 | .00300 | .00067 | .00067 | —.00033 | .00233 | .00100 |
| 24,000 | .00367 | .00067 | .00067 | .00000 | .00300 | .00067 |
| 25,000 | .00467 | .00100 | .00133 | .00066 | .00333 | .00033 |
| 26,000 | .00600 | .00133 | .00133 | .00000 | .00467 | .00134 |
| 27,000 | .00700 | .00100 | .00133 | .00000 | .00567 | .00100 |
| 28,000 | .00867 | .00167 | .00133 | .00000 | .00733 | .00166 |
| 29,000 | .00967 | .00100 | .00133 | .00000 | .00833 | .00100 |
| 30,000 | .01033 | .00066 | .00167 | .00034 | .00867 | .00034 |
| 31,000 | .01167 | .00134 | .00167 | .00000 | .01000 | .00133 |
| 32,000 | .01300 | .00133 | .00167 | .00000 | .01133 | .00133 |
| 33,000 | .01467 | .00167 | .00133 | —.00034 | .01333 | .00200 |
| 34,000 | .01633 | .00166 | .00167 | .00034 | .01467 | .00134 |
| 35,000 | .01767 | .00134 | .00167 | .00000 | .01600 | .00133 |
| 36,000 | .01933 | .00166 | .00133 | —.00034 | .01800 | .00200 |
| 37,000 | .02133 | .00200 | .00200 | .00067 | .01933 | .00133 |
| 38,000 | .02300 | .00167 | .00200 | .00000 | .02100 | .00167 |
| 39,000 | .02500 | .00200 | .00200 | .00000 | .02300 | .00200 |
| 40,000 | .02667 | .00167 | .00200 | .00000 | .02467 | .00167 |
| 41,000 | .02933 | .00266 | .00233 | .00033 | .02700 | .00233 |
| 42,000 | .03133 | .00200 | .00200 | —.00033 | .02933 | .00233 |
| 43,000 | .03367 | .00234 | .00233 | .00033 | .03133 | .00200 |
| 44,000 | .03600 | .00233 | .00233 | .00000 | .03367 | .00234 |
| 45,000 | .04000 | .00400 | .00200 | —.00033 | .03800 | .00433 |
| 46,000 | .04300 | .00300 | .00233 | .00033 | .04067 | .00267 |
| 47,000 | .04667 | .00367 | .00233 | .00000 | .04433 | .00366 |
| 48,000 | .04933 | .00266 | .00233 | .00000 | .04700 | .00267 |
| 49,000 | .05267 | .00334 | .00267 | .00034 | .05090 | .00390 |
| 50,000 | .05500 | .00233 | .00300 | .00033 | .05200 | .00233 |
| 51,000 | .06300 | .00800 | .00267 | —.00033 | .06033 | .00833 |
| 52,000 | .06633 | .00333 | .00267 | .00000 | .06367 | .00334 |
| 53,000 | .07267 | .00634 | .00300 | .00033 | .06967 | .00600 |
| 54,000 | .07933 | .00666 | .00300 | .00000 | .07633 | .00666 |
| 55,000 | .08567 | .00634 | .00300 | .00000 | .08267 | .00634 |
| 56,000 | .09533 | .00966 | .00300 | .00000 | .09233 | .00966 |
| 57,000 | .10733 | .01200 | .00333 | .00033 | .10400 | .01167 |
| 58,000 | .12267 | .01534 | .00333 | .00000 | .11933 | .01533 |
| 59,000 | .14100 | .01833 | .00333 | .00000 | .13767 | .01834 |
| 60,000 | .18200 | .04100 | 0.00400 | 0.00067 | 0.17800 | 0.04033 |
| 61,000 | 0.29100 | 0.10900 | (*) | (*) | (*) | (*) |

*Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7.8279 |
| Tensile strength, per square inch ............ pounds.. | 61,000 |
| Elastic limit ............ pounds.. | 20,000 |
| Extension, per inch, at elastic limit ............ inch.. | 0.002 |
| Extension, per inch, at rupture ............ inch.. | 0.291 |
| Hardness | 13.986 |
| Original area of cross-section ............ square inch.. | 0.3048 |
| Area after rupture ............ square inch.. | 0.1541 |
| Position of rupture | ½ from shoulder. |
| Character of fracture | Medium gray, fibrous and slightly crystalline. |

SPECIMEN II.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel, 3 inches long (between shoulders) and 0.623 inch diameter, taken from breech-receiver for 12-inch breech-loading rifled howitzer.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 4,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 5,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 6,000 | .00033 | .00000 | .00033 | .00000 | .00000 | .00000 |
| 7,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 8,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 9,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 10,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 11,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 12,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 13,000 | .00100 | .00000 | .00100 | .00000 | .00000 | .00000 |
| 14,000 | .00133 | .00033 | .00133 | .00033 | .00000 | .00000 |
| 15,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 16,000 | .00133 | .00000 | .00133 | .00000 | .00000 | .00000 |
| 17,000 | .00133 | .00000 | .00067 | — .00066 | .00067 | .00067 |
| 18,000 | .00200 | .00067 | .00067 | .00000 | .00133 | .00066 |
| 19,000 | .00300 | .00100 | .00100 | .00033 | .00200 | .00067 |
| 20,000 | .00533 | .00233 | .00100 | .00000 | .00433 | .00233 |
| 21,000 | .00567 | .00034 | .00100 | .00000 | .00467 | .00034 |
| 22,000 | .00567 | .00000 | .00100 | .00000 | .00467 | .00000 |
| 23,000 | .00567 | .00000 | .00100 | .00000 | .00467 | .00000 |
| 24,000 | .00733 | .00166 | .00133 | .00033 | .00600 | .00133 |
| 25,000 | .01067 | .00334 | .00167 | .00034 | .00900 | .00300 |
| 26,000 | .01100 | .00033 | .00167 | .00000 | .00933 | .00033 |
| 27,000 | .01133 | .00033 | .00167 | .00000 | .00967 | .00034 |
| 28,000 | .01167 | .00034 | .00133 | — .00034 | .01033 | .00066 |
| 29,000 | .01167 | .00000 | .00100 | — .00033 | .01067 | .00034 |
| 30,000 | .01200 | .00033 | .00133 | .00033 | .01067 | .00000 |
| 31,000 | .01233 | .00033 | .00100 | — .00033 | .01133 | .00066 |
| 32,000 | .01267 | .00034 | .00133 | .00033 | .01133 | .00000 |
| 33,000 | .01333 | .00066 | .00167 | .00034 | .01167 | .00034 |
| 34,000 | .01400 | .00067 | .00133 | — .00034 | .01267 | .00100 |
| 35,000 | .01567 | .00167 | .00133 | .00000 | .01433 | .00166 |
| 36,000 | .01733 | .00166 | .00167 | .00034 | .01567 | .00134 |
| 37,000 | .01933 | .00200 | .00200 | .00033 | .01733 | .00166 |
| 38,000 | .02133 | .00200 | .00167 | — .00033 | .01967 | .00234 |
| 39,000 | .02300 | .00167 | .00200 | .00033 | .02100 | .00133 |
| 40,000 | .02433 | .00133 | .00233 | .00033 | .02200 | .00100 |
| 41,000 | .02567 | .00134 | .00200 | — .00033 | .02367 | .00167 |
| 42,000 | .02700 | .00133 | .00200 | .00000 | .02500 | .00133 |
| 43,000 | .02833 | .00133 | .00200 | .00000 | .02633 | .00133 |
| 44,000 | .03033 | .00200 | .00200 | .00000 | .02833 | .00200 |
| 45,000 | .03233 | .00200 | .00233 | .00033 | .03000 | .00167 |
| 46,000 | .03500 | .00267 | .00200 | — .00033 | .03300 | .00300 |
| 47,000 | .03733 | .00233 | .00267 | .00067 | .03467 | .00167 |
| 48,000 | .04367 | .00634 | .00267 | .00000 | .04100 | .00633 |
| 49,000 | .04633 | .00266 | .00300 | .00033 | .04333 | .00233 |
| 50,000 | .04833 | .00200 | .00267 | .00033 | .04567 | .00234 |
| 51,000 | .05067 | .00234 | .00267 | .00000 | .04800 | .00233 |
| 52,000 | .05567 | .00500 | .00300 | .00033 | .05267 | .00467 |

SPECIMEN II.—*Table showing extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 53,000 | .05800 | .00233 | .00300 | .00000 | .05500 | .00233 |
| 54,000 | .06533 | .00733 | .00300 | .00000 | .06233 | .00733 |
| 55,000 | .07000 | .00467 | .00300 | .00000 | .06700 | .00467 |
| 56,000 | .07633 | .00633 | .00267 | —.00033 | .07367 | .00667 |
| 57,000 | .08433 | .00800 | .00300 | .00033 | .08133 | .00766 |
| 58,000 | .09500 | .01067 | .00300 | .00000 | .09200 | .01067 |
| 59,000 | .10767 | .01267 | .00300 | .00000 | .10467 | .01267 |
| 60,000 | .11967 | .01200 | .00333 | .00033 | .11633 | .01166 |
| 61,000 | .14933 | .02966 | 0.00367 | 0.00034 | 0.14567 | 0.02934 |
| 62,000 | 0.22667 | 0.07734 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

Specific gravity .......... 7.9422
Tensile strength, per square inch .......... pounds.. 62,000
Elastic limit .......... pounds.. 17,000
Extension, per inch, at elastic limit .......... inch.. 0.00133
Extension, per inch, at rupture .......... inch.. 0.22667
Hardness .......... 12.716
Original area of cross-section .......... square inch.. 0.3048
Area after rupture .......... square inch.. 0.1794
Position of rupture .......... ½ from center.
Character of fracture .......... Mixed, crystalline, and half fibrous.

SPECIMEN III.—*Table showing the extension, restoration, and permanent set, per inch in length, caused by the undermentioned weights, per square inch of section, acting on a solid cylinder of steel,* 3 *inches long (between shoulders) and* 0.623 *inch diameter, taken from breech-receiver for* 12-*inch breech-loading rifled howitzer.*

[Furnished by Thomas Firth & Sons, Norfolk Works, Sheffield, England.]

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1,000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 4,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 5,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7,000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8,000 | .00033 | .00033 | .00033 | .00033 | .00000 | .00000 |
| 9,000 | .00067 | .00034 | .00067 | .00034 | .00000 | .00000 |
| 10,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 11,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 12,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 13,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 14,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 15,000 | .00067 | .00000 | .00067 | .00000 | .00000 | .00000 |
| 16,000 | .00100 | .00033 | .00100 | .00033 | .00000 | .00000 |
| 17,000 | .00100 | .00000 | .00067 | —.00033 | .00033 | .00033 |
| 18,000 | .00133 | .00033 | .00100 | .00033 | .00033 | .00000 |
| 19,000 | .00167 | .00034 | .00067 | —.00033 | .00100 | .00067 |
| 20,000 | .00200 | .00033 | .00067 | .00000 | .00133 | .00033 |
| 21,000 | .00300 | .00100 | .00067 | .00000 | .00233 | .00100 |
| 22,000 | .00367 | .00067 | .00100 | .00033 | .00267 | .00034 |
| 23,000 | .00500 | .00133 | .00133 | .00033 | .00367 | .00100 |
| 24,000 | 0.00567 | 0.00067 | 0.00100 | —0.00033 | 0.00467 | 0.00100 |

SPECIMEN II.—*Table showing the extension, restoration, &c.*—Continued.

| Weight, per square inch of section. | Extension, per inch in length. | Successive extension, per inch in length. | Restoration, per inch in length. | Successive restoration, per inch in length. | Permanent set, per inch in length. | Successive permanent set, per inch in length. |
|---|---|---|---|---|---|---|
| *Pounds.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 25,000 | .00667 | .00100 | .00100 | .00000 | .00567 | .00100 |
| 26,000 | .00767 | .00100 | .00100 | .00000 | .00667 | .00100 |
| 27,000 | .00900 | .00133 | .00133 | .00033 | .00767 | .00100 |
| 28,000 | .00967 | .00067 | .00133 | .00000 | .00833 | .00066 |
| 29,000 | .01100 | .00133 | .00133 | .00000 | .00967 | .00134 |
| 30,000 | .01267 | .00167 | .00133 | .00000 | .01133 | .00166 |
| 31,000 | .01367 | .00100 | .00167 | .00034 | .01200 | .00067 |
| 32,000 | .01567 | .00200 | .00200 | .00033 | .01367 | .00167 |
| 33,000 | .01700 | .00133 | .00167 | —.00033 | .01533 | .00166 |
| 34,000 | .01800 | .00100 | .00200 | .00033 | .01600 | .00067 |
| 35,000 | .01933 | .00133 | .00167 | —.00033 | .01767 | .00167 |
| 36,000 | .02167 | .00234 | .00167 | .00000 | .02000 | .00233 |
| 37,000 | .02333 | .00166 | .00167 | .00000 | .02167 | .00167 |
| 38,000 | .02533 | .00200 | .00167 | .00000 | .02367 | .00200 |
| 39,000 | .02733 | .00200 | .00200 | .00033 | .02533 | .00166 |
| 40,000 | .02867 | .00134 | .00167 | —.00033 | .02700 | .00167 |
| 41,000 | .03067 | .00200 | .00200 | .00033 | .02867 | .00167 |
| 42,000 | .03300 | .00233 | .00200 | .00000 | .03100 | .00233 |
| 43,000 | .03500 | .00200 | .00200 | .00000 | .03300 | .00200 |
| 44,000 | .03867 | .00367 | .00233 | .00033 | .03633 | .00333 |
| 45,000 | .04067 | .00200 | .00233 | .00000 | .03833 | .00200 |
| 46,000 | .04300 | .00233 | .00233 | .00000 | .04067 | .00234 |
| 47,000 | .04833 | .00533 | .00267 | .00034 | .04567 | .00500 |
| 48,000 | .05067 | .00234 | .00233 | —.00034 | .04833 | .00266 |
| 49,000 | .05600 | .00533 | .00267 | .00034 | .05333 | .00500 |
| 50,000 | .05933 | .00333 | .00267 | .00000 | .05667 | .00334 |
| 51,000 | .06533 | .00600 | .00300 | .00033 | .06233 | .00566 |
| 52,000 | .06800 | .00267 | .00267 | —.00033 | .06533 | .00300 |
| 53,000 | .07900 | .01100 | .00267 | .00000 | .07633 | .01100 |
| 54,000 | .08233 | .00333 | .00333 | .00066 | .07900 | .00267 |
| 55,000 | .09367 | .01134 | .00300 | —.00033 | .09067 | .01167 |
| 56,000 | .10433 | .01066 | .00300 | .00000 | .10133 | .01066 |
| 57,000 | .11967 | .01534 | .00333 | .00033 | .11633 | .01500 |
| 58,000 | .13433 | .01466 | .00333 | .00000 | .13100 | .01467 |
| 59,000 | .16933 | .03500 | 0.00367 | 0.00034 | 0.16567 | 0.03467 |
| 60,000 | 0.29233 | .12300 | (*) | (*) | (*) | (*) |

* Specimen broke.

## GENERAL SUMMARY.

| | |
|---|---|
| Specific gravity | 7.9231 |
| Tensile strength, per square inch ........ pounds.. | 60,000 |
| Elastic limit ........ pounds.. | 17,000 |
| Extension, per inch, at elastic limit ........ inch.. | 0.00100 |
| Extension, per inch, at rupture ........ inch.. | 0.29233 |
| Hardness | 15.432 |
| Original area of cross-section ........ square inch.. | 0.3048 |
| Area after rupture ........ square inch.. | 0.1647 |
| Position of rupture | ½ from center. |
| Character of fracture | Medium gray, crystalline predominating. |

# APPENDIX 37 *k*.

## PROGRESS REPORT ON EXPERIMENTAL CANNON POWDERS.

The experiments in powders during the past year have been limited chiefly to such trials as have had in view the determination of the most suitable powder for the 11-inch chambered rifle.

To give, however, a clear and connected view of the results obtained in relation to those which have been presented previously, as well as to furnish data for comparison, it will be necessary to go back to some of the trials of the preceding years with the 11-inch unchambered rifle, and pass them in brief review.

In the early trials of the latter gun, during the month of August, 1879, there was employed a hexagonal powder, of the F. P. type—density 1.785, granulation 67—the results with which were not at all satisfactory, notwithstanding that the same powder had done well both with the 10-inch and the 12.25-inch unchambered rifles. It was not found practicable with the 11-inch rifle to increase the charge of F. P. powder beyond 75 pounds for a projectile of 500 pounds, without a resulting pressure of more than 40,000 pounds per square inch of bore—a pressure that was deemed inadmissible for the accompanying low velocity of 1,375 feet imparted to the projectile.

The indications all pointed towards a slower-burning powder and a larger charge. Several trial samples were accordingly procured from the Messrs. Du Pont, varying from one another in density and granulation, and even in form of grain. These powders, marked H. R., H. S., I. G., I. H., &c., are described on pages 85–90 of the Report of the Chief of Ordnance for 1879, and were tested in the 11-inch rifle in October of the same year. The sample I. H., density 1.800, granulation 40, was selected as the most promising, and an order given to Messrs. Du Pont for the manufacture of a sufficient quantity to carry on the trial of the 11-inch unchambered rifle. As compared with the F. P. and I. G. powders, the results obtained with the sample I. H. are shown in the following table:

| Date. | Number of rounds. | Gun. | Powder. | | Weight of projectile. | Velocity at 110 feet. | Pressure per □″ of bore. |
|---|---|---|---|---|---|---|---|
| | | | Nature. | Weight. | | | |
| 1879. | | | | *Pounds.* | *Pounds.* | *Feet.* | *Pounds.* |
| Aug. 4 | 1 | 11″ muzzle-loading rifle No. 1 (not chambered). | F. P. C. hexagonal. D.=1.785: Gr.=67. | 70 | 503 | 1,305 | 30,000 |
| Aug. 14 | 2 | ....do.... | F. P. B. hexagonal. D.=1.785: Gr.=67. | 70 | 506 | 1,278 | 34,500 |
| Oct. 7 | 1 | ....do.... | I. G. hexagonal. D.=1.770: Gr.=40. | 70 | 504 | 1,220 | 37,500 |
| Oct. 7 | 1 | ....do.... | I. H. hexagonal. D.=1.800: Gr.=40. | 70 | 506 | 1,227 | 23,500 |

The weight of charge with the I. H. powder was increased gradually even to 95 pounds, though 90 pounds was adopted as the charge for

continuing the proof-trials of the gun. The weight of the projectile was also increased to 550 pounds. The average results obtained from firing 172 rounds are shown in the following table:

| Date. | Number of rounds. | Gun. | Powder. | | Weight of projectile. | Velocity at 110 feet. | Pressure per □" of bore. |
|---|---|---|---|---|---|---|---|
| | | | Nature. | Weight. | | | |
| | | | | *Pounds.* | *Pounds.* | *Feet.* | *Pounds.* |
| Oct., '79, to Feb., '80. | 172 | 11" muzzle-loading rifle No. 1 (not chambered). | I. H. (A) hexagonal D.=1.800: Gr.=40. | 90 | 543 | 1,352 | 29,360 |

The above firings were interspersed at intervals with firings of 75-pound charges of F. P. powder, and a projectile of 500 pounds weight—the high pressures obtainable with the latter powder declining somewhat as the season advanced. The results which have been given above will prove interesting in comparison with those obtained from the use of the same powders in the 11-inch *chambered* rifle, which will now follow.

## 11-INCH MUZZLE-LOADING CHAMBERED RIFLE.

This gun was chambered originally for a charge of 120 pounds powder, allowing 33.41 cubic inches of space per pound of powder.

The average result obtained with the I. H. (A) powder were as follows:

| Date. | Number of rounds. | Gun. | Powder. | | Weight of projectile. | Velocity at 108 feet. | Pressure per □" of bore. |
|---|---|---|---|---|---|---|---|
| | | | Nature. | Weight. | | | |
| 1881. | | | | *Pounds.* | *Pounds.* | *Feet.* | *Pounds.* |
| Jan. 12 | 2 | 11" muzzle-loading chambered rifle No. 2. | I. H. (A) hexagonal D.=1.800: Gr.=40. | 115 | 551 | 1,401 | 31,750 |
| Jan. 12 | 2 | ....do .......... | ......do .................... | 120 | 551 | 1,418 | 33,000 |

These results were not deemed satisfactory, and accordingly a quicker powder, the F. P. (C), was tried. The average results obtained were as follows:

| Date. | Number of rounds. | Gun. | Powder. | | Weight of projectile. | Velocity at 108 feet. | Pressure per □" of bore. |
|---|---|---|---|---|---|---|---|
| | | | Nature. | Weight. | | | |
| 1881. | | | | *Lbs.* | *Lbs.* | *Feet.* | *Lbs.* |
| Jan. 16....... | 1 | 11" muzzle-loading chambered rifle No. 2. | Du Pont's F. P. (C) hexagonal; D.=1.785; Gr. =67. | 110 | 549 | 1,349 | 31,000 |
| Jan. 17 and 18 | 2 | ......do .............. | ......do .............. | 115 | 548 | 1,401 | 31,250 |
| Jan. 19 and 20 | 3 | ......do .............. | ......do .............. | 120 | 546 | 1,462 | 36,750 |
| Jan. 22 ....... | 1 | ......do .............. | ......do .............. | 122½ | 546 | 1,468 | 41,000 |

The charge of 122½ pounds appears to have been too large for the size of the chamber, as the pressure had increased over 4,000 pounds for a corresponding augmentation in the velocity of only 6 feet. It was hoped to have obtained a velocity of about 1,500 feet from this gun, without incurring a higher pressure than 40,000 pounds per square inch of bore; but, judging from the foregoing results, the attainment of this end did not seem probable with a charge of 125 pounds of powder.

The number of volumes of expansion for the 11-inch chambered rifle, using a charge of 120 pounds of powder, was 5.31, while in the 8-inch chambered rifle, using a charge of 55 pounds of powder, the number is only 4.52; it was, therefore, thought that the chamber of the 11-inch rifle could be advantageously enlarged, so as to contain a charge of powder, say, of 130 pounds. This was accordingly done by lengthening the cylindrical portion of the chamber, and thus throwing forward the front bevel or shoulder. The precise amount of the elongation was determined by calculations based upon a charge of 130 pounds, and an allowance of 33.75 cubic inches space per pound of powder. With the chamber thus enlarged, the number of volumes of expansion was 4.922. The trials were then continued with F. P. (C) hexagonal powder, gradually increasing the charge to 130 pounds. The average results were as follows:

| Date. | Number of rounds. | Gun. | Powder. | | Weight of projectile. | Velocity at 108 feet. | Pressure per □″ of bore. |
|---|---|---|---|---|---|---|---|
| | | | Nature. | Weight. | | | |
| 1881. | | | | *Lbs.* | *Lbs.* | *Feet.* | *Lbs.* |
| Mar. 12 | 2 | 11-inch muzzle-loading chambered rifle No. 2. | Du Pont's F. P. (C) hexagonal; D.=1.785; Gr.=67. | 125 | 550 | 1,457 | 35,5[illegible] |
| Mar. 12 | 1 | ......do ...... | ......do...... | 127½ | 550 | 1,480 | 37,5[illegible] |
| Mar. 12 | 2 | ......do ...... | ......do...... | 130 | 549 | 1,474 | 39,0[illegible] |

The charge of 127½ pounds gave the best results on the above date: but upon repeating the same charge a few days afterwards, the velocity fell to 1,453 feet, and a like result was obtained still a month later. With the I. H. (A) powder the results obtained were as follows:

| Date. | Number of rounds. | Gun. | Powder. | | Weight of projectile. | Velocity at 108 feet. | Pressure per □″ of bore. |
|---|---|---|---|---|---|---|---|
| | | | Nature. | Weight. | | | |
| 1881. | | | | *Lbs.* | *Lbs.* | *Feet.* | *Lbs.* |
| Apr. 28 | 1 | 11″ muzzle-loading chambered rifle No. 2. | Du Pont's I. H. (A) hexagonal; D.=1.800; Gr.=40. | 125 | 550 | 1,327 | 26,3[illegible] |
| Apr. 28 | 1 | ......do ...... | ......do...... | 130 | 550 | 1,352 | 36,5[illegible] |

The velocities so far obtained were all below the standard desired, and measures were therefore taken to procure some new samples for trial. The first sample tested, marked I. L., was a hexagonal powder, density 1.750, granulation 67, but in which the usual service proportions of the ingredients had been varied by a reduction in the saltpeter of 5 per cent. This change in the composition was authorized on the recommendation of the Messrs. Du Pont, who were of the opinion that such a powder would give very favorable results when employed in large charges, owing to the formation of the carbonic oxide in place of the

carbonic acid gas. "Such a powder," they state, "whilst burning, yields nearly double the quantity of gas that the ordinary powder does; at the same time the heat of combustion is much less, and there should be less pressure before the ball moves, and much less decreasing pressure as the ball moves to the muzzle." In other words, it is realizing, after a different manner, the very conditions sought to be obtained by air-spacing itself, *i. e.*, the production of a body of gas large in volume, but of low tension. The Messrs. Du Pont believed the above statement to be borne out in the experiments made at Fort Monroe Arsenal, from October 28 to November 1, 1875, with an 8-inch Ames rifle, firing 35 pounds of powder marked G. K., made as above, and a projectile of 176½ pounds. The pressure averaged, on the internal pressure-gauge, 22,900 pounds, and the velocity averaged 1,397 feet, which was fair for such a low pressure. The first proposition of the Messrs. Du Pont was to employ a charge of 170 pounds with the 11-inch rifle, and to make the powder of a granulation of 50 to the pound, and to maintain the same porosity of grain as in the F. P. powder. The replacement of a heavy substance like niter by a lighter one like charcoal would, of course, lower the density somewhat. It did not appear admissible, however, to employ so large a charge in a gun of which the length of bore was only 14.3 calibers; and, besides, the capacity of the chamber limited the weight of charge that could be well employed to about 130 or 135 pounds. To compensate in a measure for this restriction, the powder-makers were directed to increase the granulation to 67, keeping the density at 1.750, as first proposed. It was thought that this powder, even with a charge of 130 pounds, would afford considerable information as to the utility of pursuing experiments in the direction of a change in the service composition of powder. The records of firing with the I. L. powder were as follows:

| Date. | Number of rounds. | Gun. | Powder. Nature. | Powder. Weight. | Weight of projectile. | Velocity at 108 feet. | Pressure per □" of bore. |
|---|---|---|---|---|---|---|---|
| 1881. | | | | *Pounds.* | *Pounds.* | *Feet.* | *Pounds.* |
| March 17 | 1 | 11" muzzle-loading chambered rifle No. 2. | Du Pont's I. L. hexagonal. D.=1.750: Gr.=67. | 120 | 548 | 1,313 | 26,500 |
| March 17 | 1 | ....do | ......do | 125 | 546 | 1,361 | 28,500 |
| March 17 | 1 | ....do | ......do | 130 | 546 | 1,372 | 30,000 |
| March 17 | 1 | ....do | ......do | 135 | 546 | 1,314 | 31,500 |

The first three of the above rounds show, by the regular increase of velocity and pressure, a very uniformly burning powder; but the charge (135 pounds) was obviously too large. The results, as regards velocity, were not satisfactory. Yet, it appears not unreasonable that with a much longer gun, and using a considerable larger charge, a powder of this particular description should prove of decided advantage. Further experiments in this direction, it is thought, would be well worth trying.

The next powder that was tried in the gun was of the F. P. type—F. P. (D), density 1.785, granulation 67—of which a large lot had been procured for use with the 8-inch chambered rifles. This powder, manufactured in winter time, proved to be of a mild quality, averaging, with a

130-pound charge and shot of 544 pounds, a velocity of 1,384 feet, and pressure of 28,778 pounds.

A sample of 10 barrels of the same density and granulation as the F. P. (D), but which had undergone a longer working in the incorporating mills, was then procured. This powder, marked* I. O. was tested at the same time as two other lots furnished by Messrs. Du Pont on their own responsibility, and marked respectively I. M. and I. N. In the manufacture of the latter two powders, the usual percentage of water employed in pressing had been increased, and the two lots also differed from one another by the amount of that percentage, it being greater for the I. N.

As regards the employment of more moisture in the fabrication, the Messrs. Du Pont thought that in drying, the grains of such powder would be left more porous on the interior, whilst, on the other hand, the pores would be closed at the exterior of the grain by the deposit of niter left by the evaporating moisture. There should thus obtain a powder which at first would burn more slowly, but afterwards more rapidly than the ordinary powder; in other words, a powder involving in its *structure* the principle of progressiveness, or of *compensation*, as it has otherwise been termed. The results obtained with these three samples were as follows:

| Date. | Number of rounds. | Gun. | Powder. Nature. | Powder. Weight. | Weight of projectile. | Velocity at 108 feet. | Pressure per [illegible] of bore. |
|---|---|---|---|---|---|---|---|
| 1881. | | | | *Pounds.* | *Pounds.* | *Feet.* | *Pounds.* |
| May 19 to May 27. | 1 | 11" muzzle-loading chambered rifle No. 2. | Du Pont's I. M. hexagonal .. D. = 1.785; Gr. = 67. | 120 | 548 | 1,350 | 32,00[illegible] |
| May 19 to May 27. | 1 | ....do............ | ......do................ | 125 | 547 | 1,374 | 32,00[illegible] |
| May 19 to May 27. | 2 | ....do............ | ......do................ | 130 | 544 | 1,388 | 24,25[illegible] |
| May 19 to May 27. | 1 | ....do............ | Du Pont's I. N. hexagonal... D. = 1.785; Gr. = 67. | 120 | 548 | 1,396 | 33,[illegible] |
| May 19 to May 27. | 1 | ....do............ | ......do................ | 125 | 547 | 1,424 | 34,0[illegible] |
| May 19 to May 27. | 3 | ....do............ | ......do................ | 130 | 546½ | 1,464 | 30,[illegible] |
| May 19 to May 27. | 1 | ....do............ | Du Pont's I. O. hexagonal. .. D. = 1.785; Gr. = 67. | 120 | 548 | 1,409 | 35,5[illegible] |
| May 19 to May 27. | 1 | ....do............ | ......do................ | 125 | 547 | 1,451 | 36,0[illegible] |
| May 19 to May 27. | 5 | ....do............ | ......do................ | 130 | 546½ | 1,471 | 29,90[illegible] |

The pressures were not deemed reliable for the larger charges, as it was more than probable that under the higher tensions of the gas, the housing of the pressure-gauge, which was long, slender, and further weakened by a groove on the exterior, yielded in its walls, contracting on the knife-shoulder and thereby restraining the freedom of its movements.

The results obtained with the I. N. and the I. O. were considered on the whole as quite satisfactory, and a contract was accordingly entered into with the Messrs. Du Pont for 500 barrels, of which 400 were to be like the I. O. and 100 like I. N., excepting that the density was to be

* The amount of moisture used in pressing the I. O. was about the same as in the I. N.

lowered to 1.765. A sample lot of the latter, marked I. P., was, however, first procured and tested. The record of firing was a follows:

| Date. | Number of rounds. | Gun. | Powder. | | Weight of projectile. | Velocity at 108 feet. | Pressure per □" of bore. |
|---|---|---|---|---|---|---|---|
| | | | Nature. | Weight. | | | |
| 1881. | | | | *Pounds.* | *Pounds.* | *Feet.* | *Pounds.* |
| July 1 | 1 | 11" muzzle-loading chambered rifle No. 2. | Du Pont's I. P. hexagonal.. D.=1.765; Gr.=67. | 100 | 547 | 1,252 | 26,000 |
| July 1 | 1 | ....do | ......do | 115 | 552 | 1,375 | 30,500 |
| July 1 | 1 | ....do | ......do | 120 | 551 | 1,483 | 34,000 |
| July 1 | 1 | ....do | ......do | 125 | 551 | 1,447 | 28,500 |
| July 1 | 1 | ....do | ......do | 130 | 548 | 1,501 | 28,500 |

The same abnormal action of the pressure-gauge as before is noticeable with the larger charges. The above experimental sample is the last that has been tried up to date in the 11-inch muzzle-loading chambered rifle.

As the Messrs. Du Pont were arranging to procure an 8-inch muzzle-loading chambered rifle of their own, similar to the one in use at Sandy Hook, for the purpose of testing powders from time to time during their manufacture, it was deemed desirable to have on record certain data which would permit of drawing a comparison between the results obtained from firing the same powder in the 8 inch and the 11 inch muzzle-loading chambered rifles, inasmuch as from such a comparison the inferences from the firings of the 8-inch chambered rifle would, in future, have to be drawn. With this end in view some additional firings with certain of the above samples were made with the 8-inch muzzle-loading chambered rifle at Sandy Hook, which appear below. In these firings a shorter and more compact pressure-gauge was employed, and its indications are regarded as reliable.

The record of firing with the I. P. powder was:

| Date. | Number of rounds. | Gun. | Powder. | | Weight of projectile. | Velocity at 108 feet. | Pressure per □" of bore. |
|---|---|---|---|---|---|---|---|
| | | | Nature. | Weight. | | | |
| 1881. | | | | *Pounds.* | *Pounds.* | *Feet.* | *Pounds.* |
| July 6 | 1 | 8" muzzle-loading chambered rifle No. 28. | Du Pont's I. P. hexagonal.. D.=1.765; Gr.=67. | 55 | 179 | Lost. | 48,000 |
| July 6 | 1 | ......do | ......do | 55 | 179 | 1,675 | 50,250 |

The I. O. powder was tested in the 8-inch chambered rifle at the same time with samples from lots I. O. (A) 1, 2, and 3 of the powder being made under contract, and which had been sent to Sandy Hook for proof, but as there remained on hand only 105 pounds of the former it was necessary, in order to make up two charges of 55 pounds each, to add to it 5 pounds taken from one of the three lots of I. O. (A). The lot selected was I. O. (A) No. 1, and the two powders were thoroughly mixed together.

The record of firing was as follows:

| Date. | Number of rounds. | Gun. | Powder. Nature. | Powder. Weight. | Weight of projectile. | Velocity at 108 feet. | Pressure per □" of bore. |
|---|---|---|---|---|---|---|---|
| 1881. | | | | *Pounds.* | *Pounds.* | *Feet.* | *Pounds.* |
| August 9 | 1 | 8" muzzle-loading chambered rifle No 28. | Du Pont's I. O. (A) hexagonal No. 1. D.=1.785; Gr.=67. | 55 | 180 | 1,687 | 47,000 |
| August 9 | 1 | ....do .......... | ....do | 55 | 180 | 1,695 | 51,000 |
| August 9 | 1 | ....do .......... | Du Pont's I. O. hexagonal. D.=1.785; Gr.=67. | 55 | 180 | 1,639 | 44,000 |
| August 9 | 1 | ....do .......... | I. O. ..........<br>I. O. (A) No. 1 .......... | 50<br>5 | 180 | 1,634 | 42,000 |
| August 9 | 1 | ....do .......... | Du Pont's I. O. (A) hexagonal No. 2 D.=1.785; Gr.=67. | 55 | 180 | 1,633 | 41,500 |
| August 9 | 1 | ....do .......... | ......do .......... | 55 | 180 | 1,652 | 45,000 |
| August 9 | 1 | ....do .......... | Du Pont's I. O. (A) hexagonal No. 3. D.=1.785; Gr.=67. | 55 | 180 | 1,693 | 50,500 |
| August 9 | 1 | ....do .......... | ......do .......... | 55 | 180 | 1,662 | 48,500 |

As the lots 1 and 3 proved rather high, and as the F. P. (D) powder was known to be a mild one, it was determined to test a sample of one of the above two lots, thoroughly intermixed with an equal weight of the F. P. (D) The lots selected were I. O. (A) No. 3 and F. P. (D) No. 11. One charge composed of the latter powder alone was also prepared, to be fired at the same time.

The record of firing was as follows:

| Date. | Number of rounds. | Gun. | Powder. Nature. | Powder. Weight. | Weight of projectile. | Velocity at 108 feet. | Pressure per □" of bore. |
|---|---|---|---|---|---|---|---|
| 1881. | | | | *Pounds.* | *Pounds.* | *Feet.* | *Pounds.* |
| August 9 | 1 | 8" muzzle-loading chambered rifle No. 28. | Du Pont's I. O. (A) hexagonal No. 3. D.=1.785; Gr.=67.<br>Du Pont's F. P. (D) hexagonal No. 11. D.=1.785; Gr.=67. | 27½<br>27½ } 55 | 180 | 1,616 | 41,000 |
| August 16 | 1 | ....do .......... | Du Pont's F. P. (D) hexagonal No. 11. D.=1.785; Gr.=67. | 55 | 179 | 1,553 | 32,000 |
| August 17 | 1 | ....do .......... | Du Pont's I. O. (A) hexagonal No. 3. D.=1.785; Gr.=67.<br>Du Pont's F. P. (D) hexagonal, No. 11. D.=1.785; Gr.=67. | 27½<br>27½ } 55 | 179 | 1,605 | 40,000 |

Comparing the results obtained with mixed charges with those obtained with the component powders fired separately, it will be observed that the former occupy the position of an arithmetical mean between the latter.

With a view to determining the effect where the two component powders were not intermixed, but placed separately in the cartridge-bag, the four following rounds were fired, and under the following conditions: In the first two rounds the quicker powder—the I. O. (A) No. 3—was placed at the bottom of the cartridge-bag with the F. P. (D) No. 11 in

front; and in the last two rounds the F. P. (D) No. 11 was placed at the bottom with the I. O. (A) No. 3 in front.

The record of firing was as follows:

| Date. | Number of rounds. | Gun. | Powder. Nature. | Powder. Weight. | Weight of projectile. | Velocity at 108 feet. | Pressure per □″ of bore. |
|---|---|---|---|---|---|---|---|
| 1881. | | | | *Pounds.* | *Pounds.* | *Feet.* | *Pounds.* |
| August 16 | 1 | 8″ muzzle-loading chambered rifle No. 28. | Du Pont's I. O. (A) hexagonal No. 3. D. = 1.785; Gr. = 67.<br>Du Pont's F. P. (D) hexagonal No. 11. D. = 1.785; Gr. = 67. | 27½<br>27½ } 55 | 179 | 1,528 | 107,000 |
| August 16 | 1 | ....do.......... | I. O. (A) No. 3 ..........<br>F. P. (D) No. 11 .......... | 27½<br>27½ } 55 | 179 | 1,530 | 106,000 |
| August 16 | 1 | ....do.......... | Du Pont's F. P. (D) hexagonal No. 11. D. = 1.785; Gr. = 67.<br>Du Pont's I. O. (A) hexagonal No. 3. D. = 1.785; Gr. = 67. | 27½<br>27½ } 55 | 179 | 1,563 | 70,000 |
| August 16 | 1 | ....do.......... | F. P. (D) No. 11..........<br>I. O. (A) No. 3 .......... | 27½<br>27½ } 55 | 179 | 1,582 | 71,000 |

The above results are significant, as compared with those where the two powders were intimately mixed, and should be attributed, perhaps, to the operation of two principal causes, to wit: First, the want of simultaneousness, or, better say, of an uniform progressiveness in the explosive action of the two portions of the charge, which would give rise to interference and opposition between the elastic gases generated, and thus to the setting up of wave-action with its accompaniment of severe local pressures; and, second, the abnormally high tension thus developed acts to accelerate greatly the rate of combustion of the still unconsumed grains, which acceleration in turn would enormously increase the tension itself, and consequently the pressure on the walls of the bore.

The operation of the latter cause is particularly noticeable during the first two of the above rounds, where the quicker powder was placed at the bottom of the cartridge, the average pressure exceeding by 36,000 pounds per square inch that obtained under the contrary condition, or where the slower powder—the F. P. (D)—was placed at the bottom. In the latter case, however, the falling off in pressure may doubtless be partly accounted for by supposing that motion was more promptly imparted to the projectile thereby, giving additional space for the expansion of the gases, and thus materially lowering the tension at an earlier epoch of the explosion. The correctness of such supposition is apparently borne out by the increase in velocity, averaging 43 feet, that was gained in the last two rounds.

The pressures obtained in the above trial can be regarded as reliable, the pressure-gauge having been tested after firing the first two rounds by firing the charge of F. P. (D) No. 11 alone, given in the previous table, and after the second two rounds, by firing the second mixed round, given also in the previous table. The gun was carefully examined and star-gauged after the above firings, but showed no deterioration, and only 0″.002 additional enlargement of bore.

NOTE.—The 8-inch rifle employed in the above experiments was vented at the middle of the powder chambers.

# APPENDIX 38.

## REPORT OF EXPERIMENTS MADE WITH A VIEW OF DETERMINING THE PROPER MODE OF PACKING GUNPOWDER FOR THE MILITARY SERVICE.

Four different packing cases were used, as follows:

No. 1 consisted of a rectangular tin case, closed by an 8-inch bronze screw-cover, with gasket of leather; its size was such that it would contain 100 pounds hexagonal powder loosely packed. This was inclosed in a pine box, painted inside and out, the lid screwed on, and all the joints covered with red lead. The metal case cost $5.48, and the box $1.63.

No. 2 was the same as No. 1, except that the inner case was of zinc and the gasket was of lead. The metal case cost $6.08.

No. 3 was the same as No. 1, excepting the metal case, which was of copper, and the screw-cover had a diameter of 6 inches and a gasket of copper. The inner case cost $5.80.

No. 4 was the ordinary wooden powder barrel, the cost of which is $2.50.

One hundred pounds of Du Pont's H. T. powder were placed in each of the four cases; these were stored in May, 1879, in a stone magazine inside the fort at Sandy Hook, N. J.; the magazine was not in good condition, as the roof leaked.

The powder before being stored was tested, April 10, 1879, for pressure and velocity. Further tests of the powder were made June 26, 1880, and August 4, 1881, charges being taken from each case. The results of these trials are given in the accompanying firing record. In June, 1880, gaskets of corrugated copper were substituted for those previously in use.

### CONCLUSIONS.

The velocities obtained in successive years with charges from each case show that, though the mean velocity for all increased with time, the yearly differences were in favor of the cases lined with metal, the increase for the copper lining being somewhat greater than for the others.

The board is of the opinion that the tests made do not indicate a sufficient superiority of the cases lined with metal to warrant their use when their increased cost over the ordinary wooden powder barrel is considered.

The board is inclined to believe that a cheap and serviceable powder case, consisting of a well seasoned wooden box lined with papier-maché, might be constructed, and it does therefore recommend that the commanding officer of the Watervliet Arsenal be instructed to prepare a sample of such a case for submission to the board. In this connection the board would also state that it has requested the commanding officer of the United States Ordnance Agency to procure three of Mr. Eugene Ritter's patent powder cases, as authorized by the Chief of Ordnance January 16, 1880, with a view of having a full and thorough consideration of this important subject before any final decision is made.

Upon these considerations the board would suggest that all action on its recommendation of March 24, 1881, be suspended for the present.

*Target record of firing with 4½-inch siege rifle No. 101, at Sandy Hook, N. J.*

| | No. of fire. | Time. | Powder. Kind. | Powder. Wgt. Lbs. | Powder. Wgt. Ozs. | Projectile. Kind. | Projectile. Wgt. Lbs. | Projectile. Wgt. Ozs. | Elevation in degrees. | Pressure, pounds per square inch of bore. | Initial velocity, feet. | Recoil, feet. | Direction of wind as regards line of fire. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1879. | | | | | | | | | | | | |
| | 195 | Apr. 10 | Du Pont's H. Y. powder; density, 1.772; granulation, 3,000. | 5 | .. | Absterdam shell, filled with sand. | 25 | .. | 0 | 45,000 | 1,403 | ...... | ...... | |
| | 196 | Apr. 10 | | 5 | .. | | 25 | .. | 0 | 18,000 | 1,305 | ...... | ...... | |
| | 197 | Apr. 10 | | 5 | .. | | 25 | .. | 0 | 22,000 | 1,415 | ...... | ...... | |
| | 198 | Apr. 10 | | 5 | .. | | 25 | .. | 0 | 27,000 | 1,406 | ...... | ...... | |
| | 199 | Apr. 10 | | 5 | 8 | | 25 | .. | 0 | 28,000 | 1,475 | ...... | ...... | |
| | 200 | Apr. 10 | | 5 | 8 | | 25 | .. | 0 | 18,000 | 1,375 | ...... | ...... | |
| | 201 | Apr. 16 | | 5 | .. | | 25 | .. | 0 | 21,000 | 1,384 | ...... | ...... | |
| | 202 | Apr. 16 | | 5 | .. | | 25 | .. | 0 | 22,000 | 1,391 | ...... | ...... | |
| | 203 | Apr. 16 | | 6 | .. | | 25 | .. | 0 | 40,000 | 1,551 | ...... | ...... | |
| | 204 | Apr. 16 | | 6 | .. | | 25 | .. | 0 | 46,000 | 1,525 | ...... | ...... | At 204th round sabot stripped in flight. |
| | 205 | Apr. 16 | | 6 | .. | | 25 | .. | 0 | 50,000 | 1,535 | ...... | ...... | |
| | | 1880. | | | | | | | | | | | | |
| Barometer, 29.869; thermometer, 88; relative humidity, 50 per cent; wind, 13 miles an hour. | 257 | June 26 | Box No. 1. | 5 | .. | | 25 | .. | −¼ | 29,000 | 1,433 | 14.00 | ...... | Fired into sand butt to try powder. |
| | 258 | June 26 | | 5 | .. | | 25 | .. | −¼ | 36,500 | 1,434 | 14.00 | ...... | |
| | 259 | June 26 | | 6 | .. | | 25 | .. | −¼ | 48,000 | 1,562 | 18.75 | ...... | |
| | 260 | June 26 | | 6 | .. | | 25 | .. | −¼ | 48,000 | 1,543 | 19.00 | ...... | |
| | 261 | June 26 | | 6 | .. | | 25 | .. | −¼ | 46,500 | 1,521 | 16.50 | ...... | |
| | 262 | June 26 | Box No. 2. | 5 | .. | | 25 | .. | −¼ | 32,500 | 1,406 | 14.00 | ...... | |
| | 263 | June 26 | | 5 | .. | | 25 | .. | −¼ | 31,000 | 1,419 | 14.00 | ...... | |
| | 264 | June 26 | | 6 | .. | | 25 | .. | −¼ | 48,000 | 1,552 | 14.00 | ...... | |
| | 265 | June 26 | | 6 | .. | | 25 | .. | −¼ | 47,500 | 1,547 | 14.00 | ...... | |
| | 266 | June 26 | | 6 | .. | | 25 | .. | −¼ | 47,500 | 1,543 | 17.00 | ...... | |
| | 267 | June 26 | Box No. 3. | 5 | .. | | 25 | .. | −¼ | 19,000 | 1,376 | 13.00 | ...... | |
| | 268 | June 26 | | 5 | .. | | 25 | .. | −¼ | 35,000 | 1,400 | 15.00 | ...... | |
| | 269 | June 26 | | 6 | .. | | 25 | .. | −¼ | 47,000 | 1,500 | 16.00 | ...... | |
| | 270 | June 26 | | 6 | .. | | 25 | .. | −¼ | 47,500 | 1,588 | 16.50 | ...... | |
| | 271 | June 26 | | 6 | .. | | 25 | .. | −¼ | 47,500 | 1,546 | 19.00 | ...... | |
| | 272 | June 26 | Ordinary wooden powder barrel. | 5 | .. | | 25 | .. | −¼ | 34,000 | 1,396 | 15.00 | ...... | |
| | 273 | June 26 | | 5 | .. | | 25 | .. | −¼ | 32,000 | 1,406 | 13.00 | ...... | |
| | 274 | June 26 | | 6 | .. | | 25 | .. | −¼ | 47,500 | 1,535 | 17.00 | ...... | |
| | 275 | June 26 | | 6 | .. | | 25 | .. | −¼ | 47,500 | 1,541 | 17.00 | ...... | |
| | 276 | June 26 | | 6 | .. | | 25 | .. | −¼ | 48,000 | 1,536 | 17.50 | ...... | |

*Target record of firing with 4½-inch siege rifle No.* 101—Continued.

| | No. of fire. | Time. | Powder. Kind. | Powder. Wgt. Lbs. | Powder. Wgt. Ozs. | Projectile. Kind. | Projectile. Wgt. Lbs. | Projectile. Wgt. Ozs. | Elevation in degrees. | Pressure, pounds, per square inch of bore. | Initial velocity, feet. | Recoil, feet. | Direction of wind as regards line of fire. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1881. | | | | | | | | | | | | |
| Barometer, 30.080; thermometer, 84; relative humidity, 68 per cent.; wind, 1 mile an hour. | 304 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 1. | 5 | .. | Absterdam shell, filled with sand. | 25 | .. | −¼ | 35, 500 | 1, 461 | ..... | From right to left. | Projectile keyholed. |
| Barometer, 30.080; thermometer, 84; relative humidity, 68 per cent.; wind, 1 mile an hour. | 305 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 1. | 5 | .. | Absterdam shell, filled with sand. | 25 | .. | −¼ | 28, 000 | 1, 411 | ..... | From right to left. | |
| Barometer, 30.080; thermometer, 84; relative humidity, 68 per cent.; wind, 1 mile an hour. | 306 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 1. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¼ | 46, 500 | 1, 573 | ..... | From right to left. | |
| Barometer, 30.080; thermometer, 84; relative humidity, 68 per cent.; wind, 1 mile an hour. | 307 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 1. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 48, 000 | 1, 582 | ..... | From right to left. | |
| Barometer, 30.080; thermometer, 84; relative humidity, 68 per cent.; wind, 1 mile an hour. | 308 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 1. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 48, 000 | 1, 594 | ..... | From right to left. | Sabot stripped. |
| Barometer, 30.080; thermometer, 84; relative humidity, 68 per cent.; wind, 1 mile an hour. | 309 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 2. | 5 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 38, 000 | 1, 461 | .... | From right to left. | |
| Barometer, 30.080; thermometer, 84; relative humidity, 68 per cent.; wind, 1 mile an hour. | 310 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 2. | 5 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 32, 500 | 1, 455 | ..... | From right to left. | |
| Barometer, 30.080; thermometer, 84; relative humidity, 68 per cent.; wind, 1 mile an hour. | 311 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 2. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 48, 500 | 1, 574 | ..... | From right to left. | |
| Barometer, 30.080; thermometer, 84; relative humidity, 68 per cent.; wind, 1 mile an hour. | 312 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 2. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 48, 500 | 1, 582 | ..... | From right to left. | |
| Barometer, 30.080; thermometer, 84; relative humidity, 68 per cent.; wind, 1 mile an hour. | 313 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 2. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 47, 500 | 1, 585 | ..... | From right to left. | Fired into sand butt to try powder. |
| Barometer, 30.031; thermometer, 90; relative humidity, 62 per cent.; wind, 8 miles an hour. | 314 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 3. | 5 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 29, 500 | 1, 450 | ..... | From right to left. | |
| Barometer, 30.031; thermometer, 90; relative humidity, 62 per cent.; wind, 8 miles an hour. | 315 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 3. | 5 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 30, 000 | 1, 446 | ..... | From right to left. | |
| Barometer, 30.031; thermometer, 90; relative humidity, 62 per cent.; wind, 8 miles an hour. | 316 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 3. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 46, 500 | 1, 573 | ..... | From right to left. | |
| Barometer, 30.031; thermometer, 90; relative humidity, 62 per cent.; wind, 8 miles an hour. | 317 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 3. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 44, 500 | 1, 554 | ..... | From right to left. | |
| Barometer, 30.031; thermometer, 90; relative humidity, 62 per cent.; wind, 8 miles an hour. | 318 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Box No. 3. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 46, 500 | 1, 577 | ..... | From right to left. | |
| Barometer, 30.031; thermometer, 90; relative humidity, 62 per cent.; wind, 8 miles an hour. | 319 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Ordinary wooden powder barrel. | 5 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 18, 500 | 1, 405 | ..... | From right to left. | |
| Barometer, 30.031; thermometer, 90; relative humidity, 62 per cent.; wind, 8 miles an hour. | 320 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Ordinary wooden powder barrel. | 5 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 21, 000 | 1, 420 | ..... | From right to left. | |
| Barometer, 30.031; thermometer, 90; relative humidity, 62 per cent.; wind, 8 miles an hour. | 321 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Ordinary wooden powder barrel. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 33, 000 | 1, 534 | ..... | From right to left. | |
| Barometer, 30.031; thermometer, 90; relative humidity, 62 per cent.; wind, 8 miles an hour. | 322 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Ordinary wooden powder barrel. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 36, 000 | 1, 530 | ..... | From right to left. | |
| Barometer, 30.031; thermometer, 90; relative humidity, 62 per cent.; wind, 8 miles an hour. | 323 | Aug. 4 | Dupont's H. Y. powder; density, 1.772; granulation, 3,000. Ordinary wooden powder barrel. | 6 | .. | Absterdam shell, filled with sand. | 25 | .. | −¾ | 38, 500 | 1, 540 | ..... | From right to left. | |

The powder used during the firing noted in this report has been stored in stone magazine inside the fort at Sandy Hook, N. J., since May 2, 1879, in barrel and boxes, as follows:

Barrel, ordinary wooden powder barrel.

Box No. 1. Tin case, japanned outside, 8-inch bronze screw cover.

Box No. 2. Zinc case, 8-inch bronze screw cover.

Box No. 3. Copper case, 6-inch bronze screw cover.

All boxes having copper gaskets since June 26, 1880, and inclosed in wooden boxes, leaded joints, painted inside and out. Barrel and boxes last opened June 26, 1880, for firing, as per report of that date, and returned to magazine.

# APPENDIX 38[a].

## CONTINUED TEST OF 8-INCH BREECH-LOADING RIFLE No. 1.

[Seven plates.]

This gun has been fired since last report (Report of Chief of Ordnance, 1880, pages 232 to 239) 135 times, making the total number of rounds fired 636. The limit originally fixed upon for the endurance of this gun was 501 rounds, but upon the recommendation of the Constructor of Ordnance to the Chief of Ordnance, in letter dated September 6, 1880, and approved by the latter, 100 additional rounds were authorized to be fired for the purpose of obtaining certain information in regard to the gas-check and its seat, and also to test some varieties of projectiles suitable for breech-loaders.

A preliminary report was made by the Ordnance Board March 22, 1881, recommending slight changes in the rifling and the employment of Hotchkiss projectiles for future constructions of this caliber. A summary of the records of firing and the target records made both with the Hotchkiss and Butler projectiles are herewith appended.

Steel gas-checks (Broadwell rings) were used in most of these firings, being changed from time to time by lengthening and thinning the lip and reaming out the seat of gas-check. There was more or less escape of gas during most of this firing from the defective weld in coil tube, mentioned in report of 1880, but this seemed to be almost entirely stopped by the thin and long-lipped gas-check last used.

A table of enlargements is also inclosed, showing that the gun is still in a sound and serviceable condition.

AVER

TABLE No. 1.—*Record of firings with an experimental 8-inch breech-*

| Description of gun. | Date. | Number of rounds. | Charge. Kind of powder. |
|---|---|---|---|
| An 8-inch breech-loading rifle, converted from a 10-inch Rodman smooth bore by lining with a steel-jacketed coiled wrought iron tube, inserted from the breech, jacket of the tube being prolonged to the rear and adapted for reception of the round wedge fermeture. Caliber, 8 inches; total length of bore, 147.25 inches; length of rifled portion of bore, including bevel, 101.25 inches; length of chamber, 22 inches; diameter of bore, including grooves, 8.15 inches; number of grooves and bands, 15 each; weight of gun, 17,075 pounds. | May 19 and 25, 1880. | 2 | Du Pont's hexagonal R. V. J. Density, 1.750; granulation, 72. |
| | May 17, 18, 19, 25, 28; June 8 and 11, 1880. | 22 | |
| | July 14, 20, 21; Nov. 30; Dec. 1, 1880; March 16, 31, 1881. | 38 | |
| | Sept. 1, 1880 ....... | 2 | |
| | Sept. 17, 18, 22, 23; Nov. 18, 30; Dec. 1, 1880; March 16, 1881. | 71 | |
| | Total .......... | 135 | |

AGES.

*loading rifle from May* 17, 1880, *to March* 31, 1881, *at Sandy Hook, N. J.*

| Charge. Cartridge. Weight. | Charge. Cartridge. Height. | Charge. Cartridge. Diameter. | Projectile. Kind. | Projectile. Weight. | Projectile. Length. | Projectile. Diameter. | Velocities at 93 feet from muzzle of gun. | Velocities at the muzzle. | Maximum pressures per square inch of surface of bore. |
|---|---|---|---|---|---|---|---|---|---|
| *Lbs.* | *Ins.* | *Ins.* | | *Lbs.* | *Ins.* | *Ins.* | *Feet.* | *Feet.* | *Lbs.* |
| 30 | 19¼ | 7.25 | Butler | 177 | 20 | 7.95 | .......... | .......... | .......... |
| 35 | 22½ | 7.25 | ......do | 178 | 20 | 7.95 | 1,414 | 1,421 | 36,333 |
| | | | | | | | *At* 109 *feet.* | | |
| 35 | 22½ | 7.25 | ......do | 178 | 20 | 7.95 | 1,396 | 1,404 | 29,666 |
| 30 | 19¼ | 7.25 | Hotchkiss | 180 | 20 | 7.95 | 1,340 | 1,348 | 29,750 |
| 35 | 22½ | 7.25 | ......do | 179 | 20 | 7.95 | 1,425 | 1,434 | 36,318 |

TABLE No. 2.—*Target record of firing with 8-inch*

| | Number of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs | Projectile. Weight. Oz. | Elevation in degrees. | Direction of wind as regards line of fire. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1880. | | | | | | | ° ′ | |
| Barometer, 29.950; thermometer, 70; relative humidity, 80 per cent.; wind, 20 miles an hour. | 521 | June 11 | Du Pont's hexagonal, E. V. J. Density, 1.750; granulation, 72. | 35 | .... | Butler, resaboted. | 179 | .... | 2 40 | From left and front. |
| | 522 | June 11 | | 35 | .... | ....do ..... | 180 | .... | 2 40 | |
| | 523 | June 11 | | 35 | .... | ....do ..... | 179 | .... | 2 40 | |
| | 524 | June 11 | | 35 | .... | ....do ..... | 180 | .... | 2 40 | |
| | 525 | June 11 | | 35 | .... | ....do ..... | 179 | .... | 2 40 | |
| Barometer, 30.280; thermometer, 59; relative humidity, 59 per cent.; wind, 10 miles an hour. | 538 | Sept. 23 | | 35 | ... | Hotchkiss, 1 band, 93 per cent. copper, new. | 176 | .... | 2 40 | From rear and left. |
| | 539 | Sept. 23 | | 85 | .... | | 177 | .... | 2 42 | |
| | 540 | Sept. 23 | | 35 | .... | | 178 | .... | 2 42 | |
| | 541 | Sept. 23 | | 35 | .... | | 179 | .... | 2 42 | |
| | 542 | Sept. 23 | | 35 | .... | do.rebanded | 175 | .... | 2 42 | |
| Barometer, 30.076; thermometer, 64; relative humidity, 43 per cent.; wind, 17 miles an hour. | 543 | Sept. 30 | | 35 | .... | Hotchkiss, new, 1 copper band. | 177 | .... | 2 45 | From rear and right. |
| | 544 | Sept. 30 | | 35 | .... | | 177 | .... | 2 44 | |
| | 545 | Sept. 30 | | 35 | .... | | 178 | .... | 2 44 | |
| | 546 | Sept. 30 | | 35 | .... | | 178 | .... | 2 44 | |
| | 547 | Sept. 30 | | 35 | .... | | 178 | .... | 2 44 | |
| | 548 | Sept. 30 | | 35 | .... | | 178 | .... | 2 44 | |
| | 549 | Sept. 30 | | 35 | .... | | 178 | .... | 2 44 | |
| | 550 | Sept. 30 | | 35 | .... | | 178 | .... | 2 44 | |
| | 551 | Sept. 30 | | 35 | .... | | 178 | .... | 2 44 | |
| | 552 | Sept. 30 | | 35 | .... | | 178 | .... | 2 44 | |

*breech-loading rifle No. 1, at Sandy Hook, N. J.*

| Distance from center of target, in feet. | | | | Distance from center of impact, in feet. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Vertical. | | Horizontal. | | Vertical. | | Horizontal. | | |
| Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. | |
| ........ | 2.75 | ........ | 6.21 | ........ | 4.52 | ........ | 2.88 | Fired at mile target. Target 24′ × 40′, made of 1″ spruce boards. |
| ........ | 4.83 | ........ | 1.83 | ........ | 6.60 | 2.00 | ........ | |
| 9.25 | ........ | ........ | 4.50 | 7.48 | ........ | ........ | .67 | |
| ........ | 3.83 | ........ | 1.29 | ........ | 5.60 | 2.51 | ........ | |
| 11.00 | ........ | ........ | 5.83 | 9.23 | ........ | ........ | 1.50 | |
| 20.25 | 11.41 | ........ | 19.16 | 16.71 | 16.72 | 4.54 | 4.55 | Mean vertical deviation from center of impact, 6′.69. Mean horizontal deviation from center of impact, 1′.82. Mean deviation from center of impact, 6′.93. |
| 8.84 ÷ 5 = 1.77 | | 19.16 ÷ 5 = 3.83 | | 33.43 ÷ 5 = 6.69 | | 9.09 ÷ 5 = 1.82 | | |
| ........ | 13.00 | 3.00 | ........ | ........ | 5.25 | ........ | 2.65 | Fired at mile target. Target 25′ × 40′, made of 1″ spruce boards. |
| ........ | 5.00 | 1.50 | ........ | 2.75 | ........ | ........ | 4.15 | |
| ........ | 4.00 | 10.75 | ........ | 3.75 | ........ | 5.10 | ........ | |
| ........ | 8.75 | 3.90 | ........ | ........ | 1.00 | ........ | 2.65 | |
| ........ | 8.00 | 10.00 | ........ | ........ | .25 | 4.35 | ........ | |
| ........ | 38.75 | 28.25 | ........ | 6.50 | 6.50 | 9.45 | 9.45 | Mean vertical deviation from center of impact, 2′.60. Mean horizontal deviation from center of impact, 3′.78. Mean deviation from center of impact, 4′.60. |
| 38.75 ÷ 5 = 7.75 | | 28.25 ÷ 5 = 5.65 | | 13.00 ÷ 5 = 2.60 | | 18.90 ÷ 5 = 3.78 | | |
| ........ | .82 | ........ | 5.00 | 4.07 | ........ | ........ | .53 | Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards |
| ........ | 2.75 | ........ | 5.15 | 1.64 | ........ | ........ | .68 | |
| ........ | 8.00 | ........ | 6.00 | ........ | 3.61 | ........ | 1.53 | |
| ........ | 6.17 | ........ | .50 | ........ | 1.78 | 3.97 | ........ | |
| ........ | 6.00 | ........ | 2.25 | ........ | 1.61 | 2.22 | ........ | |
| ........ | 2.00 | ........ | 2.82 | 2.39 | ........ | 2.15 | ........ | |
| ........ | 6.17 | ........ | 7.00 | ........ | 1.78 | ........ | 2.53 | |
| .83 | ........ | ........ | 5.33 | 4.72 | ........ | ........ | .86 | |
| ........ | 5.82 | ........ | 5.00 | ........ | 1.43 | ........ | .53 | |
| ........ | 7.00 | ........ | 6.15 | ........ | 2.61 | ........ | 1.68 | |
| .33 | 44.23 | ........ | 44.70 | 12.82 | 12.82 | 8.34 | 8.34 | Mean vertical deviation from center of impact, 2′.56. Mean horizontal deviation from center of impact, 1′.67. Mean deviation from center of impact, 3′.06. |
| 43.90 ÷ 10 = 4.39 | | 44.70 ÷ 10 = 4.47 | | 25.64 ÷ 10 = 2.56 | | 16.68 ÷ 10 = 1.67 | | |

TABLE No. 2.—*Target record of firing with 8-inch breech-*

| | Number of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs | Projectile. Weight. Oz. | Elevation in degrees. | Direction of wind as regards line of fire. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1880. | | | | | | | ° ′ | |
| Barometer, 30.356; thermometer, 40; relative humidity, 56 per cent.; wind, 10 miles an hour. | 590 | Nov. 30 | Du Pont's hexagonal, E. V. J. Density, 1.750; granulation, 72. | 35 | .... | Hotchkiss, new. | 180 | .... | 2 50 | From right to left. |
| | 591 | Nov. 30 | | 35 | .... | ....do ..... | 180 | .... | 2 50 | |
| | 592 | Nov. 30 | | 35 | .... | ....do ..... | 180 | .... | 2 50 | |
| | 593 | Nov. 30 | | 35 | .... | ....do ..... | 180 | .... | 2 50 | |
| | 594 | Nov. 30 | | 35 | .... | ....do ..... | 180 | .... | 2 50 | |
| | 605 | Nov. 30 | | 35 | .... | ....do ..... | 180 | .... | 2 50 | |
| | 606 | Nov. 30 | | 35 | .... | ....do ..... | 180 | .... | 2 50 | |
| | 607 | Nov. 30 | | 35 | .... | ....do ..... | 180 | .... | 2 50 | |
| | 608 | Nov. 30 | | 35 | .... | ....do ..... | 180 | .... | 2 50 | |
| | 609 | Nov. 30 | | 35 | .... | ....do ..... | 180 | .... | 2 50 | |
| Barometer, 30.359; thermometer, 40; relative humidity, 56 per cent.; wind, 10 miles an hour. | 595 | Nov. 30 | | 35 | .... | Butler, new | 177 | .... | 2 50 | From right to left. |
| | 596 | Nov. 30 | | 35 | .... | ....do ..... | 177 | .... | 2 50 | |
| | 597 | Nov. 30 | | 35 | .... | ....do ..... | 177 | .... | 2 50 | |
| | 598 | Nov. 30 | | 35 | .... | ....do ..... | 177 | .... | 2 50 | |
| | 599 | Nov. 30 | | 35 | .... | ....do ..... | 177 | .... | 2 50 | |
| | 600 | Nov. 30 | | 35 | .... | ....do ..... | 177 | .... | 2 55 | |
| | 601 | Nov. 30 | | 35 | .... | ....do ..... | 177 | .... | 2 55 | |
| | 602 | Nov. 30 | | 35 | .... | ....do ..... | 177 | .... | 3 05 | |
| | 603 | Nov. 30 | | 35 | .... | ....do ..... | 177 | .... | 3 00 | |
| | 604 | Nov. 30 | | 35 | .... | ....do ..... | 177 | .... | 3 00 | |
| | | 1881. | | | | | | | | |
| Barometer, 30.024; thermometer, 53; relative humidity, 80 per cent.; wind, 12 miles an hour. | 621 | Mar. 16 | | 35 | .... | Hotchkiss, new, 1 copper band. | 180 | .... | 2 50 | From rear and right. |
| | 622 | Mar. 16 | | 35 | .... | | 180 | .... | 2 50 | |
| | 623 | Mar. 16 | | 35 | .... | | 180 | .... | 2 50 | |
| | 624 | Mar. 16 | | 35 | ... | | 180 | .... | 2 50 | |
| | 625 | Mar. 16 | | 35 | .... | | 180 | .... | 2 50 | |

*loading rifle No.* 1, *at Sandy Hook, N. J.*—Continued.

| Distance from center of target, in feet. | | | | Distance from center of impact, in feet. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Vertical. | | Horizontal. | | Vertical. | | Horizontal. | | |
| Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. | |
| ........ | 7.32 | ........ | 3.50 | ........ | 1.80 | ........ | .87 | |
| ........ | 3.00 | ........ | 1.50 | 2.52 | ........ | 1.13 | ........ | |
| ........ | 7.17 | ........ | 5.00 | ........ | 1.65 | ........ | 2.37 | |
| ........ | 6.17 | ........ | 4.75 | ........ | .65 | ........ | 2.12 | |
| ........ | 2.00 | ........ | 2.75 | 3.52 | ........ | ........ | .12 | Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards. |
| Under | target . | ........ | ........ | ........ | ........ | ........ | ........ | |
| ........ | 4.75 | ........ | ........ | .77 | ........ | 2.63 | ........ | |
| ........ | 7.50 | ........ | ........ | ........ | 1.98 | 2.63 | ........ | |
| Under | target . | ........ | ........ | ........ | ........ | ........ | ........ | |
| ........ | 6.25 | ........ | 3.54 | ........ | .73 | ........ | .91 | |
| ........ | 44.16 | ........ | 21.04 | 6.81 | 6.81 | 6.39 | 6.39 | Mean vertical deviation from center of impact, 1′.70. Mean horizontal deviation from center of impact, 1′.60. Mean deviation from center of impact, 2′.34. |
| 44.16 ÷ 8 = 5.52 | | 21.04 ÷ 8 = 2.63 | | 13.62 ÷ 8 = 1.70 | | 12.78 ÷ 8 = 1.60 | | |
| ........ | 3.42 | ........ | .83 | .48 | ........ | ........ | .17 | |
| ........ | 7.42 | ........ | .83 | ........ | 3.52 | ........ | .17 | |
| Under | target . | ........ | ........ | ........ | ........ | ........ | ........ | |
| 50 yds. | short .. | ........ | ........ | ........ | ........ | ........ | ........ | |
| 50 yds. | short .. | ........ | ........ | ........ | ........ | ........ | ........ | Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards. |
| 6 yds. | short .. | ........ | ........ | ........ | ........ | ........ | ........ | |
| 50 yds. | short .. | ........ | ........ | ........ | ........ | ........ | ........ | |
| 100 yds. | beyond | ........ | ........ | ........ | ........ | ........ | ........ | |
| 4.00 | ........ | 2.33 | ........ | 7.90 | ........ | 2.99 | ........ | |
| ........ | 8.76 | ........ | 3.31 | ........ | 4.86 | ........ | 2.65 | |
| 4.00 | 19.60 | 2.33 | 4.97 | 8.38 | 8.38 | 2.99 | 2.99 | Mean vertical deviation from center of impact, 4′.19. Mean horizontal deviation from center of impact, 1′.50. Mean deviation from center of impact, 4′.45. |
| 15.60 ÷ 4 = 3.90 | | 2.64 ÷ 4 = .66 | | 16.76 ÷ 4 = 4.19 | | 5.98 ÷ 4 = 1.50 | | |
| ........ | .35 | ........ | .65 | 3.52 | ........ | ........ | 1.02 | |
| ........ | 5.50 | 1.00 | ........ | ........ | 1.63 | .63 | ........ | |
| ........ | 7.33 | | .25 | ........ | 3.46 | | .62 | Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards. |
| ........ | 3.17 | ........ | 1.25 | .70 | ........ | ........ | 1.62 | |
| ........ | 3.00 | 3.00 | ........ | .87 | ........ | 2.63 | ........ | |
| ........ | 19.35 | 4.00 | 2.15 | 5.09 | 5.09 | 3.26 | 3.26 | Mean vertical deviation from center of impact, 2′.04. Mean horizontal deviation from center of impact, 1′.30. Mean deviation from center of impact, 2′.41. |
| 19.35 ÷ 5 = 3.87 | | 1.85 ÷ 5 = .37 | | 10.18 ÷ 5 = 2.04 | | 6.52 ÷ 5 = 1.30 | | |

TABLE No. 2.—*Target record of firing with 8-inch breech-*

| | Number of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs. | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs. | Projectile. Weight. Oz. | Elevation in degrees. | Direction of wind as regards line of fire. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1881. | | | | | | | ° ′ | |
| Barometer, 30.024; thermometer, 53; relative humidity, .80 per cent.; wind, 12 miles an hour. | 627 | Mar. 16 | Du Pont's hexagonal, E. V. J. Density, 1.750; granulation, 72. | 35 | .... | Butler, re-saboted. | 179 | .... | 3 05 | From rear and right. |
| | 628 | Mar. 16 | | 35 | .... | ....do ..... | 179 | .... | 3 05 | |
| | 629 | Mar. 16 | | 35 | .... | ....do ..... | 179 | .... | 3 05 | |
| | 630 | Mar. 16 | | 35 | .... | ....do ..... | 179 | .... | 3 05 | |
| | 631 | Mar. 16 | | 35 | .... | ....do ..... | 179 | .... | 3 05 | |
| Barometer, 29.23; thermometer, 40; relative humidity, 82 per cent.; wind, 10 miles an hour. | 632 | Mar. 31 | | 35 | .... | Butler, new | 176 | .... | 3 05 | From left to right. |
| | 633 | Mar. 31 | | 35 | .... | ....do ..... | 176 | .... | 3 05 | |
| | 634 | Mar. 31 | | 35 | .... | ....do ..... | 177 | .... | 3 05 | |
| | 635 | Mar. 31 | | 35 | .... | ....do ..... | 177 | .... | 3 05 | |
| | 636 | Mar. 31 | | 35 | .... | Butler, re-saboted. | 176 | .... | 3 05 | |

*loading rifle No.* 1, *at Sandy Hook, N. J.*—Continued.

| Distance from center of target, in feet. | | | | Distance from center of impact, in feet. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Vertical. | | Horizontal. | | Vertical. | | Horizontal. | | |
| Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. | |
| Target omitted on account of irregular flight of projectiles...... | | | | | | | | Projectile used in rounds 627 to 631, inclusive, were out of a lot of 80 received from South Boston foundry under invoice of December 14, 1880, and were found to be defective in consequence of bad material of sabot. |
| ........ | 2.75 | 4.25 | ........ | ........ | .88 | ........ | 1.10 | Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards. |
| ........ | 4.00 | 5.15 | ........ | ........ | 2.13 | ........ | .20 | |
| ........ | 2.73 | 3.00 | ........ | ........ | .86 | ........ | 2.35 | |
| 2.00 | ........ | 9.00 | ........ | 3.87 | ........ | 3.65 | ........ | |
| Struck 20′ in front of target ........ | | | | | | | | |
| 2.00 | 9.48 | 21.40 | ........ | 3.87 | 3.87 | 3.65 | 3.65 | Mean vertical deviation from center of impact, 1′.98. Mean horizontal deviation from center of impact, 1′.82. |
| 7.48 ÷ 4 = 1.87 | | 21.40 ÷ 4 = 5.35 | | 7.74 ÷ 4 = 1.98 | | 7.30 ÷ 4 = 1.82 | | Mean deviation from center of impact, 2′.69. |

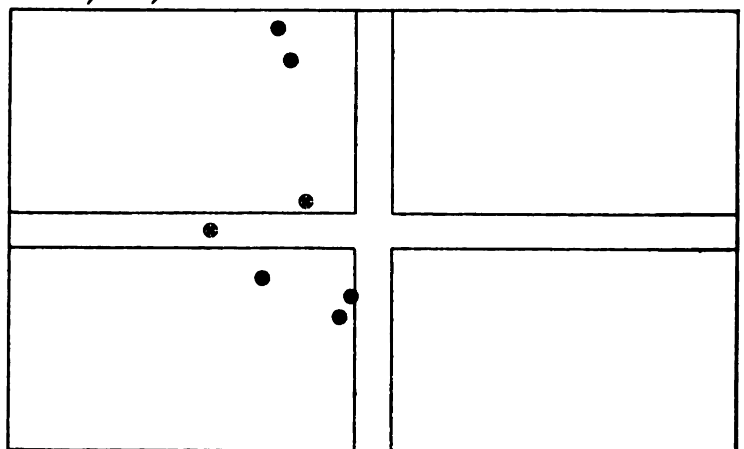
TABLE No. 3.—*Table of enlargements of 8-inch breech-loading rifle No. 1.*

| Inches from muzzle. | Original diameter of bore. | Enlargements of bore, including "setting up" of tube, after— | | |
|---|---|---|---|---|
| | | A total of 501 rounds. | A total of 568 rounds. | A total of 696 rounds. |
| | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 99 | 7.990 | 0.006 | Not taken. | Not taken. |
| 98 | .990 | .005 | Not taken. | Not taken. |
| 97 | .990 | .005 | 0.010 | 0.019 |
| 96 | .990 | .005 | .010 | .016 |
| 95 | .990 | .005 | .010 | .016 |
| 94 | .990 | .006 | .009 | .015 |
| 93 | .990 | .006 | .009 | .014 |
| 92 | .990 | .008 | .008 | .014 |
| 91 | .990 | .006 | .007 | .011 |
| 90 | .990 | .006 | .006 | .010 |
| 89 | .990 | .005 | .005 | .010 |
| 88 | .990 | .004 | .005 | .009 |
| 87 | .990 | .004 | .005 | .008 |
| 86 | .990 | .005 | .005 | .009 |
| 85 | .991 | .007 | .007 | .007 |
| 84 | .993 | .006 | .006 | .006 |
| 83 | .995 | .006 | .007 | .007 |
| 82 | .995 | .008 | .008 | .009 |
| 81 | .996 | .009 | .009 | .009 |
| 80 | .996 | .009 | .009 | .009 |
| 78 | .997 | .009 | .009 | .009 |
| 76 | .997 | .008 | .008 | .008 |
| 74 | .996 | .008 | .008 | .009 |
| 72 | .996 | .008 | .008 | .014 |
| 70 | .995 | .005 | .005 | .009 |
| 68 | .993 | .006 | .006 | .009 |
| 66 | .995 | .004 | .004 | .005 |
| 64 | .995 | .005 | .005 | .006 |
| 62 | .995 | .006 | .006 | .008 |
| 60 | .995 | .006 | .006 | .009 |
| 58 | .995 | .008 | .008 | .009 |
| 56 | .995 | .007 | .007 | .009 |
| 54 | .995 | .005 | .005 | .009 |
| 52 | .995 | .005 | .005 | .008 |
| 50 | .995 | .004 | .004 | .007 |
| 48 | .995 | .004 | .004 | .007 |
| 46 | .995 | .003 | .003 | .007 |
| 44 | .995 | .003 | .003 | .006 |
| 42 | .995 | .003 | .003 | .006 |
| 40 | .995 | .003 | .003 | .006 |
| 38 | .996 | .003 | .003 | .005 |
| 36 | .996 | .004 | .004 | .006 |
| 34 | .996 | .004 | .004 | .007 |
| 32 | .996 | .004 | .004 | .006 |
| 30 | .996 | .004 | .004 | .006 |
| 28 | .996 | .004 | .004 | .006 |
| 26 | .996 | .004 | .004 | .006 |
| 24 | .996 | .004 | .004 | .007 |
| 22 | .996 | .004 | .004 | .007 |
| 20 | .996 | .004 | .004 | .007 |
| 18 | .996 | .004 | .004 | .007 |
| 16 | .996 | .004 | .004 | .007 |
| 14 | .996 | .004 | .004 | .007 |
| 12 | .995 | .005 | .005 | .007 |
| 10 | .995 | .005 | .005 | .007 |
| 8 | .995 | .005 | .005 | .007 |
| 6 | .995 | .005 | .005 | .008 |
| 4 | .995 | .005 | .005 | .009 |
| 2 | .995 | .005 | .005 | .009 |
| 1 | .995 | .005 | .005 | .009 |

Target Record of Sinch B. L. Rifle # 1
At Sandy Hook N. J. June 11th 1880
Target One mile from gun

Number of shots fired 5

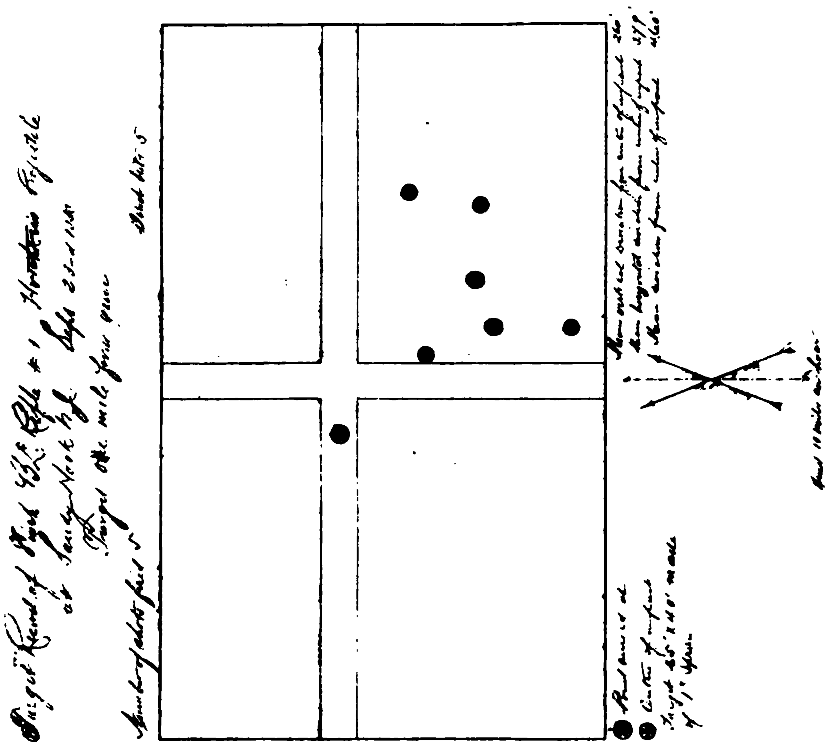
Direct hits 5



● Center of impact
● Point aimed at.
Target 24'x40' made of 1" spruce boards

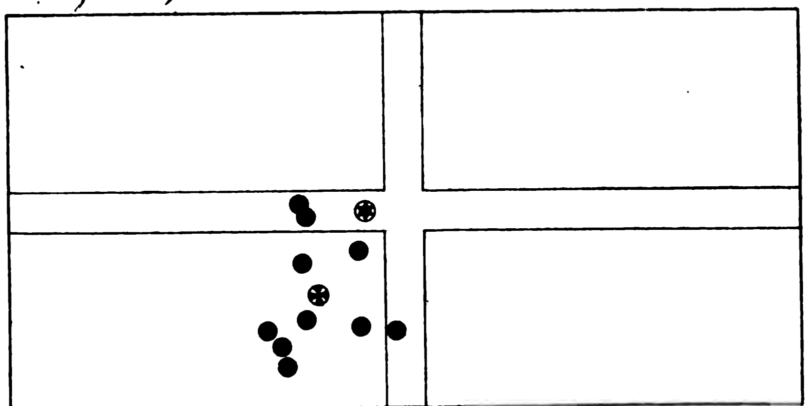
Mean vertical deviation from center of impact 6.69'
Mean horizontal deviation from center of impact 1.82'
Mean deviation from center of impact 6.95'

Wind 20 miles an hour


at Sandy Hook N.J.
Target one mile from gun
Number of shots fired 5
Direct hits 5
Point struck
Centre of impact
Mean vertical deviation from centre of impact 2.60'
Mean horizontal deviation from centre of impact 3.79'
Mean deviation from centre of impact 4.60'
Wind 10 miles an hour

Target Record of 8inch B.L. Rifle #1 Using Hotchkiss projectile
at Sandy Hook N.J. Sept. 23d 1880
Target One mile from gun

Number of shots fired 10 Direct hits 10



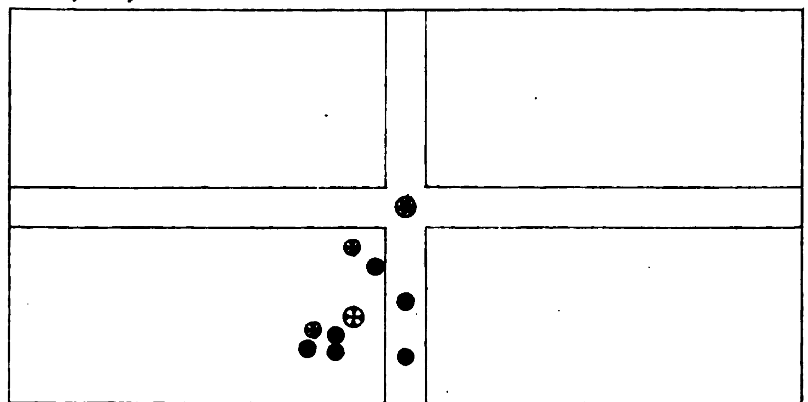
Point aimed at
Centre of impact
Target 20'x40' made of 1" Spruce boards

Mean vertical deviation from centre of impact 2.56'
Mean horizontal deviation from centre of impact 1.67'
Mean deviation from centre of impact 3.06'

Wind 17 miles an hour

Target Record of 8 inch B. L. Rifle #1 Hotchkiss projectile,
at Sandy Hook N. J. Nov 30th 1880
Target One mile from gun

Number of shots fired 10 Direct hits 8 Missed 2.



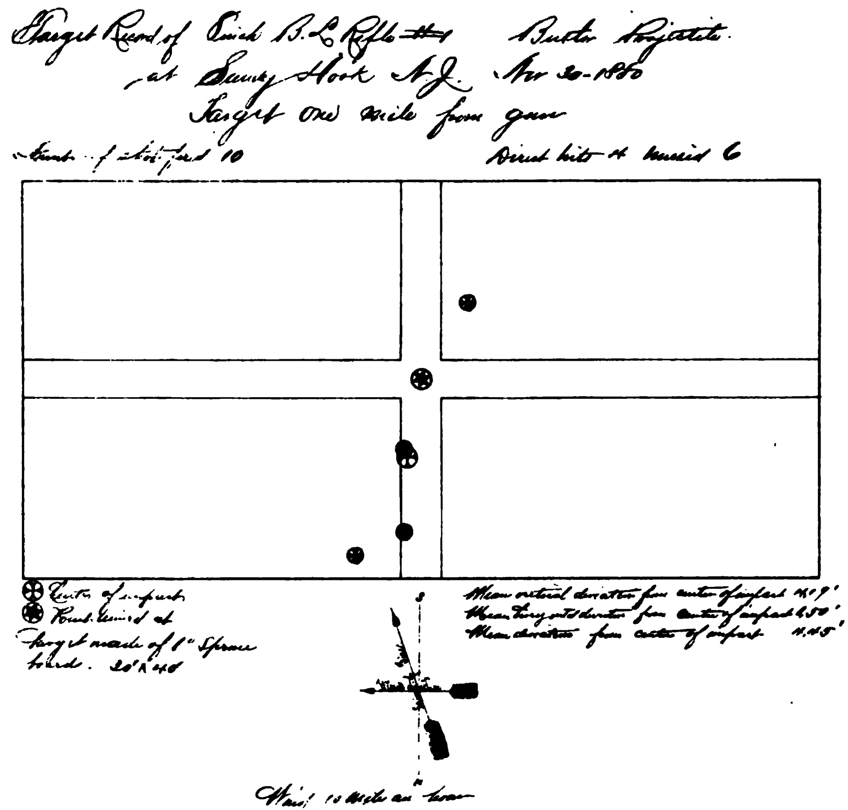
Center of impact.

Point aimed at

Target 20' x 40' made of 1" Spruce boards

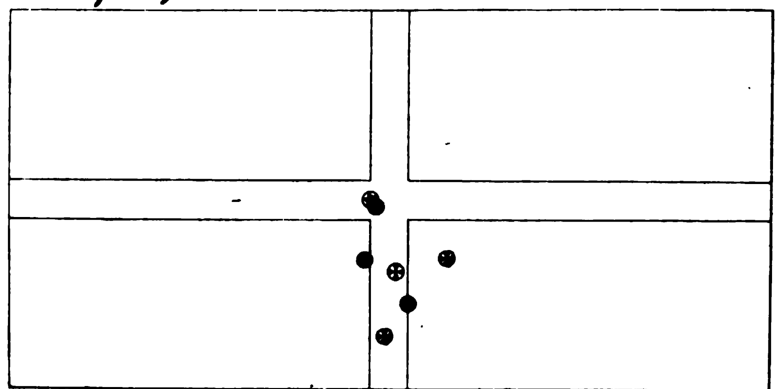
Mean vertical deviation from center of impact 1.70'
Mean horizontal deviation from center of impact 1.60'
Mean deviation from center of impact 2.3[illegible]'

Wind 10 miles an hour


Target Record of 8 inch B. L. Rifle #1 Butler Projectile
at Sandy Hook N.J. Nov 30-1880
Target One mile from gun
Number of shots fired 10
Direct hits 4 missed 6
Centre of impact
Point aimed at
Target made of 1" Spruce board. 20' x 40'
Mean vertical deviation from centre of impact 11.9'
Mean horizontal deviation from centre of impact 2.50'
Mean deviation from centre of impact 11.15'
S
N
Wind 10 Miles an hour

Target Record of 8in B.L. Rifle #1 using Hotchkiss projectile
at Sandy Hook N.J. March tenth 1881
Target one mile from gun

Number of shots fired 5 Number hit 5



Point aimed at
Center of impact

Target 20' x 40' made of
1" Spruce boards

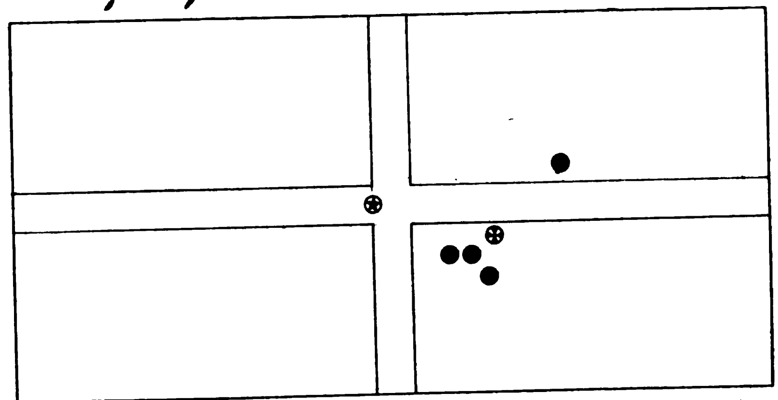
Mean vertical deviation from center of impact 2.04'
Mean horizontal deviation from center of impact 1.30'
Mean deviation from center of impact 2.41'

Wind 12 miles an hour

PLATE VII.

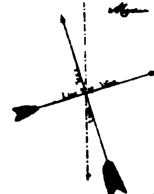
Target Record of 8" B.L. Rifle #1 Using Butler projectile
at Sandy Hook N.J. March 31st 1881
Target One mile from gun

Number of shots fired 5 Direct hits 4 missed 1



⊛ Point aimed at
⊛ Center of impact
Target 20' x 40' made of 1" Spruce boards

Mean vertical deviation from center of impact 1.98'
Mean horizontal deviation from center of impact 1.82'
Mean deviation from center of impact 2.69'



Wind 10 miles an hour

Appendix 3S—1881.

# APPENDIX $38^b$.

## REPORT ON 3.20-INCH BREECH-LOADING CHAMBERED RIFLES.

[Twenty-four plates.]

The guns of this caliber fired at Sandy Hook were Nos. 774, 3, and 4. The first one of these guns is described on pages 42 and 43 Report of Chief of Ordnance of 1880, and the carriage from which it was fired is described on pages 45 and 46 of the same report, and a progress report was made by the board September 21, 1880. (See same report, page 249). This gun is there called a 3″.18 caliber, but the bore was found upon accurate measurement to be more nearly 3″.19, and was so irregular in its diameters that it was ground out to a diameter of 3″.20. The records of firing with this gun from this date, June 16, 1880, that is, from the sixty-second round only, are forwarded, but all the records of firing with this gun are only of importance as a test of the carriage and of the breech mechanism, for the bore was again slightly enlarged for the firings after October 20, 1880, and no very satisfactory results were obtained, as far as accuracy was concerned, on account of the irregularity of the bore.

Guns 3 and 4 were more accurately bored out, and rifled for a 3″.20 bore, and their form of chamber is shown in report of Constructor of Ordnance for current year. Gun No. 3 had its shot-chamber arranged for the Hotchkiss projectile, and gun No. 4 was chambered for the use of the Butler projectile. Both of these guns were rifled differently from gun No. 774, having a little less twist and depth of grooves. (See report of Constructor of Ordnance for the current year.)

### GUN-CARRIAGE.

The carriage from which all these firings were made is described in the report of the Constructor of Ordnance for the current year.

This carriage was turned over to the board by the Constructor of Ordnance, by indorsement of March 9, 1881, and a preliminary report made by the board on June 28, 1881, when, with the approval of the Chief of Ordnance, it was turned over to the commanding officer of Watervliet Arsenal, for the purpose of correcting the defects developed in the course of firing and any other details, to meet the requirements of service. Tracings of the different targets made are inclosed.

### POWDER.

The powder employed in these experiments was of Du Pont's manufacture, marked I. K. and I. K. A, granulation 2,200, density 1.725, and gave excellent results, the average velocity being for charges of 2½ and 3 pounds 1,351 and 1,494 feet, respectively.

### PROJECTILE.

The projectiles employed were the Butler expanding, adapted to this breech-loading system, and the Hotchkiss banded projectile. Plates I and II show the dimensions of these projectiles.

### RECOMMENDATIONS.

1. The board would recommend that for all future conversions of the 3-inch wrought iron rifle that this system of breech mechanism be followed, and that the bore be rifled in accordance with the plan submitted by the Constructor of Ordnance in the current year's report.

2. The board would further recommend the employment of the Hotchkiss projectile for these guns, as it is cheaper than the Butler, equal if not superior in accuracy, and allows less escape of gas.

TABLE No. 1.—*Target record of firing with 3.20-inch breech-*

| | Number of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs. | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs. | Projectile. Weight. Oz. | Elevation in degrees. | Diameter of shot. | Length of shot. | Direction of wind as regards line of fire. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1880. | | | | | | | ° ′ | ″ | | |
| Barometer, 29.713; thermometer, 78; relative humidity, 47; wind west, 16 miles an hour. | 63 | June 30 | Du Pont's I. K. Density, 1.725; granulation, 2,200. | 2 | 8 | Hotchkiss, new, 1 brass band 1¼″ wide. | 12 | .... | 3¼ | ...... | .... | From right to left. |
| [redacted] | 64 | July 14 | | 2 | 8 | Hotchkiss, 1 brass band 1¼″ wide, 2¼ calibers long; diameter across body of shot, 3″.18; across band, 3″.25. | 12 | .... | 3 20 | ...... | .... | ........ |
| Barometer, 29.918; thermometer, 84; relative humidity, 50; wind, 8 miles an hour. | 65 | July 14 | | 2 | 8 | | 12 | .... | 3 20 | ...... | .... | From front and left. |
| | 66 | July 14 | | 2 | 8 | | 12 | .... | 3 22 | ...... | .... | |
| | 67 | July 14 | | 2 | 8 | | 12 | .... | 3 25 | ...... | .... | |
| | 68 | July 14 | | 2 | 8 | | 12 | .... | 3 31 | ...... | .... | |
| | 69 | July 14 | | 2 | 8 | | 12 | .... | 3 31 | ...... | .... | |
| | 70 | July 14 | | 2 | 8 | | 12 | .... | 3 31 | ...... | .... | |
| | 71 | July 14 | | 2 | 8 | | 12 | .... | 3 29 | ...... | .... | |
| | 72 | July 14 | | 2 | 8 | | 12 | .... | 3 29 | ...... | .... | |
| | 73 | July 15 | | 2 | 8 | | 12 | .... | 3 29 | ...... | .... | ........ |
| | 74 | July 15 | | 2 | 8 | | 12 | .... | 3 25 | ...... | .... | ........ |
| Barometer, 29.672; thermometer, 85; relative humidity, 72; wind, 11 miles an hour. | 75 | July 16 | | 2 | 8 | Hotchkiss, 1 brass band 1¼″ wide. | 12 | .... | 3 30 | 3.18 | 2.8 | From front to rear. |
| | 76 | July 16 | | 2 | 8 | | 12 | .... | 3 30 | 3.18 | 2.8 | |
| | 77 | July 16 | | 2 | 8 | | 12 | .... | 3 30 | 3.18 | 2.8 | |
| | 78 | July 16 | | 2 | 8 | | 12 | .... | 3 30 | 3.18 | 2.8 | |
| | 79 | July 16 | | 2 | 8 | | 12 | .... | 3 30 | 3.18 | 2.8 | |
| | 80 | July 16 | | 2 | 8 | | 12 | .... | 3 30 | 3.18 | 2.8 | |
| | 81 | July 16 | | 2 | 8 | | 12 | .... | 3 30 | 3.18 | 2.8 | |
| | 82 | July 16 | | 2 | 8 | | 12 | .... | 3 30 | 3.18 | 2.8 | |
| | 83 | July 16 | | 2 | 8 | | 12 | .... | 3 30 | 3.18 | 2.8 | |
| | 84 | July 16 | | 2 | 8 | | 12 | .... | 3 30 | 3.18 | 2.8 | |
| | 85 | July 16 | | 2 | 8 | Hotchkiss, 1 copper corrugated band, 1¼″ wide. | 12 | .... | 3 30 | 3.18 | 2.5 | ........ |
| | 86 | July 16 | | 2 | 8 | | 12 | .... | 3 30 | 3.18 | 2.5 | ........ |

*loading chambered rifle No. 774, at Sandy Hook, N. J.*

| Distance from center of target, in feet. | | | | Distance from center of impact, in feet. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Vertical. | | Horizontal. | | Vertical. | | Horizontal. | | |
| Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. | |
| Fired down beach. Clear smooth sound ........ | | | | | | | | |
| Fired at mile target. Sighting shot over........ | | | | | | | | |
| ........ | 6.90 | 10.24 | ........ | ........ | 4.97 | 3.72 | ........ | |
| ........ | 6.95 | 10.96 | ........ | ........ | 5.02 | 4.44 | ........ | |
| Under | target . | ........ | ........ | ........ | ........ | ........ | ........ | |
| .90 | ........ | 10.45 | ........ | 2.83 | ........ | 3.93 | ........ | Fired at 1 mile target. Target 20' × 40', made of 1" spruce boards. |
| 4.90 | ........ | ........ | 3.35 | 6.83 | ........ | ........ | 9.87 | |
| Over | target . | ........ | ........ | ........ | ........ | ........ | ........ | |
| ........ | 1.60 | 4.30 | ........ | .33 | ........ | ........ | 2.22 | |
| Struck 5' in front of target........ | | | | | | | | |
| 5.80 | 15.45 | 35.95 | 3.35 | 9.99 | 0.99 | 12.09 | 12.09 | Mean vertical deviation from center of impact, 4'.00. Mean horizontal deviation from center of impact, 4'.84. Mean deviation from center of impact, 6'.28. |
| 9.65 ÷ 5 = 1.93 | | 32.60 ÷ 5 = 6.52 | | 19.98 ÷ 5 = 4.00 | | 24.18 ÷ 5 = 4.84 | | |
| Sighting shots fired at mile target........ | | | | | | | | |
| 4.20 | ........ | ........ | 4.50 | 6.49 | ........ | 3.78 | ........ | |
| Missed | target. | ........ | ........ | ........ | ........ | ........ | ........ | |
| Missed | target. | ........ | ........ | ........ | ........ | ........ | ........ | Target 20' × 40', made of 1" spruce boards. |
| Missed | target. | ........ | ........ | ........ | ........ | ........ | ........ | |
| ........ | 9.67 | ........ | .11 | ........ | 7.38 | ........ | 2.72 | Sabot stripped near gun. |
| ........ | 2.75 | ........ | 2.50 | ........ | .56 | 4.78 | ........ | |
| 2.50 | ........ | ........ | 12.42 | 4.79 | ........ | ........ | 4.14 | |
| Missed | target. | ........ | ........ | ........ | ........ | ........ | ........ | |
| ........ | 5.75 | ........ | 10.00 | ........ | 3.46 | ........ | 1.72 | |
| Missed | target. | ........ | ........ | ........ | ........ | ........ | ........ | |
| 6.70 | 18.17 | ........ | 41.42 | 11.28 | 11.30 | 8.56 | 8.58 | Mean vertical deviation from center of impact, 4'.52. Mean horizontal deviation from center of impact, 3'.43. Mean deviation from center of impact, 5'.68. |
| 11.47 ÷ 5 = 2.29 | | 41.42 ÷ 5 = 8.28 | | 22.58 ÷ 5 = 4.52 | | 17.14 ÷ 5 = 3.43 | | |
| Fired at mile target. Direct hit 9' above 9' left........ | | | | | | | | |
| Fired at mile target. Direct hit 7' above 7' left........ | | | | | | | | |

TABLE No. 1.—*Target record of firing with 3.20-inch breech-loading*

| | Number of fire. | Time. | Powder. Kind. | Powder. Wgt. Lbs. | Powder. Wgt. Oz. | Projectile. Kind. | Projectile. Wgt. Lb | Projectile. Wgt. Oz | Elevation in degrees. | Pressure, pounds per square inch of bore. | Initial velocity, feet. | Diameter of projectile. | Length of shot. | Diameter of band. | Direction of wind as regards line of fire. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1880. | | | | | | | ° ′ | | | ″ | | ″ | |
| | 87 | July 16 | | 2 | 8 | | 12 | ... | 3 30 | ...... | ..... | 3.18 | 2.8 | ..... | |
| | 88 | July 16 | | 2 | 8 | | 12 | ... | 3 30 | ...... | ..... | 3.18 | 2.8 | ..... | |
| | 89 | July 16 | | 2 | 8 | | 12 | ... | 3 30 | ...... | ..... | 3.18 | 2.8 | .... | |
| | 90 | July 16 | | 2 | 8 | | 12 | ... | 3 30 | ...... | ..... | 3.18 | 2.8 | ..... | |
| Barometer, 29.624; thermometer, 88; relative humidity, 66; wind 8 miles an hour. | 91 | July 16 | | 2 | 8 | Hotchkiss, 1 copper corrugated band, 1¼″ wide. | 12 | ... | 3 30 | ...... | ..... | 3.18 | 2.8 | ..... | From front and right. |
| | 92 | July 16 | | 2 | 8 | | 12 | ... | 3 30 | ...... | ..... | 3.18 | 2.8 | ..... | |
| | 93 | July 16 | | 2 | 8 | | 12 | ... | 3 30 | ...... | ..... | 3.18 | 2.8 | ..... | |
| | 94 | July 16 | | 2 | 8 | | 12 | ... | 3 30 | ...... | ..... | 3.18 | 2.8 | ..... | |
| | 95 | July 16 | | 2 | 8 | | 12 | ... | 3 30 | ...... | .... | 3.18 | 2.8 | ..... | |
| | 96 | Sept. 2 | | 2 | 8 | | 12 | ... | 0 | 21000 | 1377 | 3.18 | .... | 3.27 | |
| | 97 | Sept. 2 | | 2 | 8 | | 12 | ... | 0 | 19500 | 1362 | 3.18 | .... | 3.27 | |
| | 98 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | Good | ..... | 3.18 | .... | 3.27 | |
| Barometer, 30.146; thermometer, 73; relative humidity, 76; wind, 14 miles an hour. | 99 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | .do .. | ..... | 3.18 | .. | 3.27 | From left and front. |
| | 100 | Sept. 2 | Du Pont's I. K. Density, 1.725; granulation, 2,200. | 2 | 8 | | 12 | .. | 3 30 | .do .. | ..... | 3.18 | .... | 3.27 | |
| | 101 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | | ..... | 3.18 | .... | 3.27 | |
| | 102 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | Eccentric. | ..... | 3.18 | .... | 3.27 | |
| | 103 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | | ..... | 3.18 | .... | 3.27 | |
| | 104 | Sept. 2 | | 2 | 8 | Hotchkiss, 1 brass band. | 12 | ... | 3 30 | | ..... | 3.18 | .... | 3.27 | |
| | 105 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | Eccentric. | ..... | 3.18 | .... | 3.27 | |
| | 106 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | | ..... | 3.18 | .... | 3.27 | |
| | 107 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | | ..... | 3.18 | .... | 3.27 | |
| Barometer, 30.093; thermometer, 76; relative humidity, 64; wind, 16 miles an hour. | 108 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | Fair. | ..... | 3.18 | .... | 3.27 | From front and left. |
| | 109 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | .do .. | ..... | 3.18 | .... | 3.27 | |
| | 110 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | .do .. | ..... | 3.18 | .... | 3.27 | |
| | 111 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | .do .. | ..... | 3.18 | .... | 3.27 | |
| | 112 | Sept. 2 | | 2 | 8 | | 12 | ... | 3 30 | Good | ..... | 3.18 | .... | 3.27 | |

*chambered rifle No. 774, at Sandy Hook, N. J.*—Continued.

| Length of projectile in calibers. | Distance from center of target, in feet. | | | | Distance from center of impact, in feet. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | Vertical. | | Horizontal. | | Vertical. | | Horizontal. | | |
| | Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. | |
| ...... | ........ | 7.17 | 2.00 | ...... | ........ | 5.89 | ........ | 1.22 | |
| ...... | ........ | 7.83 | 19.50 | ...... | ........ | 6.55 | 16.28 | ...... | |
| ...... | 1.25 | ........ | 1.42 | ...... | 2.53 | ........ | ........ | 1.80 | |
| ...... | ........ | 7.00 | ........ | 4.50 | ........ | 5.72 | ........ | 7.72 | |
| ...... | 3.00 | ........ | ........ | 3.50 | 4.28 | ........ | ........ | 6.72 | Target 20′ × 40′, made of 1″ spruce boards. |
| ...... | 6.00 | ........ | 3.83 | ...... | 7.28 | ........ | .61 | ...... | |
| ...... | 2.00 | ........ | ........ | 2.50 | 3.28 | ........ | ........ | 5.72 | |
| ...... | ........ | 3.00 | ........ | 1.25 | ........ | 1.72 | ........ | 4.47 | |
| ...... | 1.17 | ........ | 14.00 | ...... | 2.45 | ........ | 10.78 | ...... | |
| | 13.42 | 25.00 | 40.75 | 11.75 | 19.82 | 19.88 | 27.67 | 27.65 | Mean vertical deviation from center of impact, 4′.41. Mean horizontal deviation from center of impact, 6′.15. |
| | 11.58 + 9 = 1.28 | | 29.00+9 = 3.22 | | 39.70 + 9 = 4.41 | | 55.32+9 = 6.15 | | Mean deviation from center of impact, 7′.56. |
| 2.50 | Fired into sand butt.......... | | | | | | | | |
| 3.00 | | | | | | | | | |
| 2.50 | ........ | 8.00 | 16.00 | ...... | ........ | 2.97 | 11.84 | ...... | |
| 2.50 | ........ | 6.00 | 12.00 | ...... | ........ | .97 | 7.84 | ...... | |
| 2.50 | ........ | 8.33 | 10.00 | ...... | ........ | 3.30 | 5.84 | ...... | Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards. |
| 2.50 | ........ | 5.33 | ........ | 8.00 | ........ | .30 | ........ | 12.16 | |
| 2.50 | .50 | ........ | ........ | 8.00 | 5.53 | ........ | ........ | 12.16 | |
| 2.50 | ........ | 3.00 | 3.00 | ...... | 2.03 | ........ | ........ | 1.16 | |
| | .50 | 30.66 | 41.00 | 16.00 | 7.56 | 7.54 | 25.52 | 25.48 | Mean vertical deviation from center of impact, 2′.52. Mean horizontal deviation from center of impact, 8′.50. |
| | 30.16 + 5 = 5.03 | | 25 + 6 = 4.16 | | 15.10 + 6 = 2.52 | | 51 + 6 = 8.50 | | Mean deviation from center of impact, 8′.87. |
| 3.00 | ........ | 9.00 | ........ | .50 | ........ | 6.49 | .82 | ...... | |
| 3.00 | ........ | 8.83 | 6.67 | ...... | ........ | 6.32 | 7.49 | ...... | |
| 3.00 | ........ | 4.75 | .83 | ...... | ........ | 2.24 | 1.65 | ...... | |
| 3.00 | Struck 6′ in front of target.......... | | | | | | | | |
| 3.00 | ........ | 6.42 | ........ | 6.50 | ........ | 3.91 | ........ | 5.68 | Fired at mile target. Target 20′ × ′40, made of 1″ spruce boards. |
| 3.00 | 9.58 | ........ | ........ | 6.67 | 12.09 | ........ | ........ | 5.85 | |
| 3.00 | 4.33 | ........ | 1.25 | ...... | 6.84 | ........ | 2.07 | ...... | |
| 3.00 | Over and struck 75 yards in rear of target.......... | | | | | | | | |
| 3.00 | Over and struck 80 yards in rear of target.......... | | | | | | | | |
| | 13.91 | 29.00 | 8.75 | 13.67 | 18.96 | 18.96 | 11.53 | 11.53 | Mean vertical deviation from center of impact, 6′.32. Mean horizontal deviation from center of impact, 3′.84. |
| | 15.09 + 6 = 2.52 | | 4.92 + 6 = .82 | | 37.89 + 6 = 6.32 | | 23.06+6 = 3.84 | | Mean deviation from center of impact, 7′.39. |

TABLE No. 1.—*Target record of firing with 3.20-inch breech-loading*

| | Number of fire. | Time. | Powder. Kind. | Powder. Wgt. Lbs. | Powder. Wgt. Oz. | Projectile. Kind. | Projectile. Wgt. Lbs. | Projectile. Wgt. Oz. | Elevation in degrees. | Pressure, pounds per square inch of bore. | Instrumental velocity, taken at 89' from muzzle. | Recoil, feet. | Diameter of projectile. | Direction of wind as regards line of fire. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1880. | | | | | | | ° ′ | | Feet. | | ″ | |
| | 113 | Sept. 2 | Du Pont's I. K. Density, 1.725; granulation, 2,200. | 2 | 8 | Hotchkiss, 1 brass band. | 12 | .. | 0 | ...... | ...... | .. | 3.18 | From front & left. |
| Barometer, 29.966; thermometer, 77; relative humidity, 82; wind, 16 miles an hour. | 114 | Sept. 3 | | 2 | 8 | ....do.............. | 12 | .. | 0 | ...... | ...... | .. | 3.18 | |
| | 115 | Sept. 3 | | 2 | 8 | ....do.............. | 12 | .. | 0 | ...... | ...... | .. | 3.18 | |
| | 116 | Sept. 3 | | 2 | 8 | ....do.............. | 12 | .. | 0 | ...... | ...... | .. | 3.18 | |
| Barometer, 29.829; thermometer, 59; relative humidity, 80; wind, 30 miles an hour. | 117 | Sept. 15 | | 2 | 8 | Hotchkiss shell, with 1 brass band 1″ wide, 2 ribs on shell. | 12 | .. | +¼ | 18,500 | 1,374 | 18 | 3.18 | From rear and right. |
| | 118 | Sept. 15 | | 2 | 8 | ....do.............. | 12 | .. | ¼ | 18,500 | 1,360 | 18 | 3.18 | |
| | 119 | Sept. 15 | | 2 | 8 | ....do.............. | 12 | .. | ¼ | 19,000 | 1,354 | 18 | 3.18 | |
| | 120 | Sept. 15 | | 2 | 8 | Hotchkiss shot, with 1 brass band 1¼″ wide. 3 ribs on shot. | 12 | .. | ¼ | 21,500 | 1,370 | 19 | 3.18 | |
| | 121 | Sept. 15 | | 2 | 8 | ....do.............. | 12 | .. | ¼ | 21,500 | 1,390 | 19 | 3.18 | |
| | 122 | Sept. 15 | | 2 | 8 | ....do.............. | 12 | .. | ¼ | 21,500 | 1,381 | 19 | 3.18 | |
| Barometer, 29.949; thermometer, 80; relative humidity, 55; wind, 4 miles an hour. | 123 | Sept. 17 | | 2 | 8 | ....do..shell ....... | 11 | 12 | 3 30 | Hotchkiss percussion rear fuze. | Bursting charge, 7¼ ounces. | .. | 3.18 | From rear to left. |
| | 124 | Sept. 17 | | 2 | 8 | ....do..shell ....... | 11 | 12 | 3 15 | | | .. | 3.18 | |
| | 125 | Sept. 17 | | 2 | 8 | ....do..shell ....... | 11 | 12 | 3 23 | | | .. | 3.18 | |
| | 126 | Sept. 17 | | 2 | 8 | ....do..shell ....... | 11 | 12 | 3 23 | | | .. | 3.18 | |
| | 127 | Sept. 17 | | 2 | 8 | ....do..shell ....... | 11 | 12 | 0 45 | | | .. | 3.18 | |
| | 128 | Sept. 17 | | 2 | 8 | ....do..shell ....... | 11 | 12 | 0 45 | | | .. | 3.18 | |
| | 129 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 23 | ...... | ...... | .. | 3.18 | |
| | 130 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 23 | ...... | ...... | .. | 3.18 | |
| | 131 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 23 | ...... | ...... | .. | 3.18 | |
| | 132 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 25 | ...... | ...... | .. | 3.18 | |
| | 133 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 25 | ...... | ...... | .. | 3.18 | |
| | 134 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 25 | ...... | ...... | .. | 3.18 | |
| | 135 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 25 | ...... | ...... | .. | 3.18 | |
| | 136 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 25 | ...... | ...... | .. | 3.18 | |
| | 137 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 25 | ...... | ...... | .. | 3.18 | |
| | 138 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 25 | ...... | ...... | .. | 3.18 | |
| | 139 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 25 | ...... | ...... | .. | 3.18 | |
| | 140 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 25 | ...... | ...... | .. | 3.18 | |
| | 141 | Sept. 17 | | 2 | 8 | ....do..shot ....... | 12 | .. | 3 25 | ...... | ...... | .. | 3.18 | |
| | 142 | Sept. 17 | | 2 | .. | ....do..shell ....... | 11 | 12 | −1¼ | Hotchkiss percussion rear fuze. | Bursting charge, 7¼ ounces. | .. | 3.18 | |
| | 143 | Sept. 17 | | 2 | .. | ....do..shell ....... | 11 | 12 | − ¼ | | | .. | 3.18 | |
| | 144 | Sept. 17 | | 2 | .. | ... do..shell ....... | 11 | 12 | − ¼ | | | .. | 3.18 | |
| | 145 | Sept. 17 | | 2 | 8 | ... do..shell ....... | 11 | 4 | + ¼ | | | .. | 3.18 | |

*chambered rifle No. 774, at Sandy Hook, N. J.*—Continued.

| Diameter of band. | Length of projectile in calibers. | Distance from center of target, in feet. Vertical. Above. | Distance from center of target, in feet. Vertical. Below. | Distance from center of target, in feet. Horizontal. Right. | Distance from center of target, in feet. Horizontal. Left. | Distance from center of impact, in feet. Vertical. Above. | Distance from center of impact, in feet. Vertical. Below. | Distance from center of impact, in feet. Horizontal. Right. | Distance from center of impact, in feet. Horizontal. Left. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| " | | | | | | | | | | |
| 3.28 | 2.50 | Fired into sand butt | | | | | | | | |
| 3.29 | 2.50 | | | | | | | | | |
| 3.30 | 2.50 | | | | | | | | | |
| 3.29 | 2.50 | | | | | | | | | |
| 3.29 | 2.8 | Fired into sand butt. 8 ounces of lead and 4 ounces of sand put in shell to bring it up to 12 pounds. Shell selected from rough castings and turned down at this place. | | | | | | | | |
| 3.29 | 2.8 | | | | | | | | | |
| 3.29 | 2.8 | | | | | | | | | |
| 3.28 | 3.0 | Fired into sand butt. Shot selected from lot of thirty on hand and ready for firing. | | | | | | | | |
| 3.28 | 3.0 | | | | | | | | | |
| 3.28 | 3.0 | | | | | | | | | |
| ..... | 2.8 | Fired at mile target. Struck ground 150 yards in rear of target and burst. | | | | | | | | Bolt at axle holding brace on left side of carriage to trail broke during firing, and was immediately replaced. From examination of the ground between gun and target it is evident that three others of these projectiles, besides the two noted, stripped in flight. |
| ..... | 2.8 | Fired at mile target. Struck ground 20 yards in front of target; no burst. | | | | | | | | |
| ..... | 2.8 | Fired at mile target. Direct hit. Struck ground twice; no burst. | | | | | | | | |
| ..... | 2.8 | Fired at mile target. Direct hit. Struck ground three times; no burst. | | | | | | | | |
| ..... | 2.8 | Fired down beach. Burst on striking ground second time ... | | | | | | | | |
| ..... | 2.8 | Fired down beach. No burst ..... | | | | | | | | |
| ..... | 2.5 | Fired at mile target. Sighting shots ..... | | | | | | | | |
| ..... | 2.5 | | | | | | | | | |
| ..... | 2.5 | | | | | | | | | |
| ..... | 2.5 | 9.00 | ....... | ....... | 2.00 | 10.11 | ....... | ....... | ....... | |
| ..... | 2.5 | 2.00 | ....... | 1.33 | ..... | 3.11 | ....... | 3.33 | ..... | |
| ..... | 2.5 | ....... | 2.75 | ....... | 10.25 | ....... | 1.64 | ....... | 8.25 | |
| ..... | 2.5 | ....... | 3.17 | ....... | 5.75 | ....... | 2.06 | ....... | 3.75 | |
| ..... | 2.5 | ....... | 2.00 | ....... | 12.00 | ....... | .89 | ....... | 10.00 | Fired at mile target. Target 20' × 40', made of 1" spruce boards. |
| ..... | 2.5 | ....... | 6.00 | ....... | | ....... | 4.89 | 2.00 | ..... | |
| ..... | 2.5 | ....... | 6.17 | 13.67 | ..... | ....... | 5.06 | 15.67 | ..... | Band stripped. |
| ..... | 2.5 | Missed target and struck 100 yards beyond ..... | | | | | | | | |
| ..... | 2.5 | .25 | ....... | ....... | 1.00 | 1.36 | ....... | 1.00 | ..... | |
| ..... | 2.5 | Missed target and struck 100 yards beyond ..... | | | | | | | | Band stripped. |
| | | 11.25 | 20.09 | 15.00 | 31.00 | 14.58 | 14.54 | 22.00 | 22.00 | Mean vertical deviation from center of impact, 3'.64. |
| | | 8.84 ÷ 8 = 1.11 | | 16 ÷ 8 = 2.00 | | 29.12 ÷ 8 = 3.64 | | 44 ÷ 8 = 5.50 | | Mean horizontal deviation from center of impact, 5'.50. Mean deviation from center of impact, 6'.60. |
| ..... | 2.8 | Fired at 200-yard target to try rear fuzes. Target 4 inches thick; direct hit; no burst. | | | | | | | | |
| ..... | 2.8 | Fired at 200-yard target to try rear fuzes. Target 4 inches thick; burst on striking target. | | | | | | | | |
| ..... | 2.8 | Fired at 200-yard target to try rear fuzes. Target 4 inches thick; direct hit; no burst. | | | | | | | | |
| ..... | 2.8 | Fired into sand butt. Fuze did not ignite. At round 145, bolt, holding brace to top of elevating screw, broke. | | | | | | | | |

TABLE No. 1.—*Target record of firing with 3.20-inch breech-loading*

| | Number of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs | Projectile. Weight. Oz. |
|---|---|---|---|---|---|---|---|---|
| Barometer, 30.246; thermometer, 78; relative humidity, 42; wind, 4 miles an hour. | 146 | 1880. Sept. 23 | Du Pont's I. K. Density, 1.725; granulation, 2,200. | 2 | 8 | Hotchkiss (new) shell with rear fuze, 1 brass band 1¼″ wide, 3 ribs on shell, shell 2.8 calibers long, not loaded. | 11 | 4 |
| | 147 | Sept. 23 | ......do ............... | 2 | 8 | Hotchkiss (new) shot, 1 brass band 1¼″ wide, 2 ribs on shot, shot 3 calibers long. | 12 | .... |
| | 148 | Sept. 23 | ......do ............... | 2 | 8 | Hotchkiss (new) shot, 1 brass band 1¼″ wide, 3 ribs on shot, shot 3 calibers long | 12 | .... |
| | 149 | Sept. 23 | ......do ............... | 2 | 8 | Hotchkiss (new) shot, 1 brass band 1¼″ wide, 3 ribs on shot, shot 3 calibers long. | 12 | .... |
| | 150 | Sept. 23 | ......do ............... | 2 | 8 | Hotchkiss (new) shot, 1 brass band 1¼″ wide, 3 ribs on shot, shot 3 calibers long. | 12 | .... |
| | 151 | Sept. 23 | ......do ............... | 2 | 8 | Hotchkiss (new) shot, 1 brass band 1¼″ wide, 3 ribs on shot, shot 3 calibers long. | 12 | .... |
| | 152 | Sept. 23 | ......do ............... | 2 | 8 | Hotchkiss (old) shell with rear fuze, 1 brass band 1¼″ wide, 3 ribs on shell, shell 3 calibers long, loaded. | 11 | 12 |
| | 153 | ......... | ......................... | ... | ... | ......................... | ... | ... |
| | 154 | ......... | ......................... | ... | ... | ......................... | ... | ... |
| | 155 | ......... | ......................... | ... | ... | ......................... | ... | ... |
| | 156 | ......... | ......................... | ... | ... | ......................... | ... | ... |
| | 157 | ......... | ......................... | ... | ... | ......................... | ... | ... |
| | 158 | ......... | ......................... | ... | ... | ......................... | ... | ... |
| Barometer, 30.295; thermometer, 51; relative humidity, 59; wind, 4 miles an hour. | 159 | Oct. 20 | Du pont's I. K. Density, 1.725; granulation, 2,200. | 2 | 8 | Hotchkiss, 1 copper band 1¼″ wide (95 per cent. copper, 5 per ct. spelter), 3 ribs on band, shot 3 calibers long. | 12 | .... |
| | 160 | Oct. 20 | ......do ............... | 2 | 8 | ......do ............... | 12 | .... |
| | 161 | Oct. 20 | ......do ............... | 2 | 8 | ......do ............... | 12 | .... |
| | 162 | Oct. 20 | ......do ............... | 2 | 8 | ......do ............... | 12 | .... |
| Barometer, 30.071; thermometer, 53; relative humidity, 67; wind, 8 miles an hour. | 163 | Oct. 27 | ......do ............... | 2 | 8 | Hotchkiss, 1 copper band 1¼″ wide (95 per cent. copper, 5 per ct. spelter), 5 ribs on band, shot 2.5 calibers long. | 11 | 12 |
| | 164 | Oct. 27 | ......do ............... | 2 | 8 | ......do ............... | 11 | 12 |

*chambered rifle No. 774, at Sandy Hook, N. J.*—Continued.

| Elevation in degrees. | Pressure, pounds per square inch of bore. | Initial velocity, feet. | Recoil, feet. | Diameter across shot. | Diameter across band. | Diameter as far as band goes on shot. | Direction of wind as regards line of fire. | Base of shot. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| ° ′ | | | | " | " | " | | " | |
| −½ | 20,000 | 1,403 | .... | 3.18 | 3.28 | ...... | From rear and right. | ...... | Fired into sand butt. Fuze exploded. |
| −½ | 19,000 | 1,368 | .... | 3.18 | 3.28 | ...... | | ...... | Fired into sand butt. |
| 1½ | ...... | ...... | .... | 3.18 | 3.28 | ...... | | 3.14 | Fired down beach. |
| 1 40 | ...... | ...... | .... | 3.18 | 3.28 | ...... | | 3.14 | Do. |
| 1 40 | ...... | ...... | .... | 3.18 | 3.28 | ...... | | 3.14 | Do. |
| 1 40 | ...... | ...... | .... | 3.18 | 3.28 | ...... | | 3.14 | Do. |
| 1 40 | ...... | ...... | .... | 3.18 | 3.28 | ...... | | 3.14 | Fired down beach. Shell did not explode. |
| ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | These rounds were not fired in the presence of the board, being fired for the purpose of observing the effect of slightly enlarging the bore of the gun on the band of the projectile, and hence no record of them are in the files of the board. |
| ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | |
| ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | |
| ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | |
| ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | |
| ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | |
| +½ | ...... | 1,323 | 21 | 3.18 | 3.31 | 3.14 | ...... | ...... | Fired into sand butt. |
| ½ | ...... | 1,341 | 21 | 3.18 | 3.31 | 3.14 | ...... | ...... | |
| ½ | ...... | 1,354 | 21 | 3.18 | 3.32 | 3.14 | ...... | ...... | |
| ½ | ...... | 1,353 | 21 | 3.18 | 3.32 | 3.14 | ...... | ...... | |
| 7 30 | ...... | ...... | .... | 3.18 | 3.31 | 3.14 | ...... | ...... | Fired over water. Clear smooth sound. |
| 7 30 | ...... | ...... | .... | 3.18 | 3.31 | 3.14 | ...... | ...... | |

TABLE No. 1.—*Target record of firing with 3.20-inch breech-loading*

| | Number of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs | Projectile. Weight. Oz. | Elevation in degrees. | Length of projectile in calibers. | Number of grooves under the band. | Direction of wind as regards line of fire. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Barometer, 30.224; thermometer, 52; relative humidity, 66; wind, 16 miles an hour. | 165 | 1880. Nov. 17 | Du Pont's I. K. Density, 1.725; granulation, 2,200. | 2 | 8 | Hotchkiss, 1 copper band, 97 per cent. copper, band 1½" wide; diameter across band, 3".31; diameter across body of shot, 3".18; diameter as far as band goes on shot, 3".14. Rebanded shot. | 12 | .... | 3° 30′ | 3 | 3 | From rear and right. |
| | 166 | Nov. 17 | | 2 | 8 | | 12 | .... | 3 30 | 3 | 3 | |
| | 167 | Nov. 17 | | 2 | 8 | | 12 | .... | 3 33 | 3 | 3 | |
| | 168 | Nov. 17 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 3 | |
| | 169 | Nov. 17 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 3 | |
| | 170 | Nov. 17 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 3 | |
| | 171 | Nov. 17 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 3 | |
| | 172 | Nov. 17 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 3 | |
| | 173 | Nov. 17 | | 2 | 8 | ....do....new shot. | 12 | .... | 3 35 | ..... | 3 | |
| | 174 | Nov. 17 | | 2 | 8 | ....do....new shot. | 12 | .... | 3 35 | ..... | 4 | |
| | 175 | Nov. 17 | | 2 | 8 | ....do....new shot. | 12 | .... | 3 35 | ..... | 4 | |
| | 176 | Nov. 17 | | 2 | 8 | ....do....new shot. | 12 | .... | 3 35 | ..... | 4 | |
| Barometer, 30.389; thermometer, 30; relative humidity, 47; wind, 10 miles an hour. | 177 | Nov. 19 | | 2 | 8 | Hotchkiss, 1 copper band, 1¼" wide, 95 per cent. copper, 5 per cent. spelter; diameter across band, 3".31; across body of shot, 3".18; ribs, 3".14. New shot. | 12 | .... | 3 35 | 3 | 5 | From rear and left. |
| | 178 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 5 | |
| | 179 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 5 | |
| | 180 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 5 | |
| | 181 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 5 | |
| | 182 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 5 | |
| | 183 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 5 | |
| | 184 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 5 | |
| | 185 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 5 | |
| | 186 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 3 | 5 | |
| | 187 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 2½ | 3 | |
| | 188 | Nov. 19 | | 2 | 8 | | 12 | .... | 3 35 | 2½ | 4 | |
| | 189 | Nov. 19 | | 2 | 8 | ....do....rebanded shot. | 12 | .... | 3 35 | 2½ | 4 | |
| | 190 | Nov. 19 | | 2 | 8 | ....do....rebanded shot. | 12 | .... | 3 35 | 2½ | 4 | |
| | 191 | Nov. 19 | | 2 | 8 | ....do....rebanded shot. | 12 | .... | 3 35 | 2½ | 4 | |

*chambered rifle No. 774, at Sandy Hook, N. J.*—Continued.

| Distance from center of target, in feet. | | | | Distance from center of impact, in feet. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Vertical. | | Horizontal. | | Vertical. | | Horizontal. | | |
| Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. | |
| Fired at mile target; sighting shots | | | | | | | | |
| ........ | .17 | 10.75 | ........ | 4.33 | ........ | ........ | 1.31 | Target No. 1.—Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards. |
| ........ | 5.17 | 11.00 | ........ | ........ | 0.67 | ........ | 1.06 | |
| ........ | 8.16 | 14.43 | ........ | ........ | 3.66 | 2.37 | ........ | |
| ........ | 13.50 | 36.18 | ........ | 4.33 | 4.33 | 2.37 | 2.37 | Mean vertical deviation from center of impact, 2′.89. |
| 13.50 ÷ 3 = 4.50 | | 36.18 ÷ 3 = 12.06 | | 8.66 ÷ 3 = 2.89 | | 4.74 ÷ 3 = 1.58 | | Mean horizontal deviation from center of impact, 1′.58. Mean deviation from center of impact, 3′.29. |
| ........ | 2.00 | 6.00 | ........ | 1.06 | ........ | 1.08 | ........ | Target No. 2.—Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards. |
| ........ | 4.83 | 7.43 | ........ | ........ | 1.77 | 2.51 | ........ | |
| ........ | 3.00 | 6.17 | ........ | .06 | ........ | 1.25 | ........ | |
| ........ | 2.17 | 1.25 | ........ | .89 | ........ | ........ | 3.67 | |
| ........ | 2.83 | 2.75 | ........ | .23 | ........ | ........ | 2.17 | |
| ........ | 3.53 | 5.92 | ........ | ........ | .47 | 1.00 | ........ | |
| ........ | 18.36 | 29.52 | ........ | 2.24 | 2.24 | 5.84 | 5.84 | Mean vertical deviation from center of impact, 0′.75. |
| 18.36 ÷ 6 = 3.06 | | 29.52 ÷ 6 = 4.92 | | 4.48 ÷ 6 = .75 | | 11.68 ÷ 6 = 1.95 | | Mean horizontal deviation from center of impact, 1′.95. Mean deviation from center of impact, 2′.09. |
| Fired at mile target; sighting shots | | | | | | | | |
| 9.00 | ........ | ........ | 3.00 | 11.89 | ........ | ........ | .96 | Target No. 3.—Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards. |
| ........ | 3.44 | ........ | 1.00 | ........ | .55 | 1.04 | ........ | |
| ........ | 9.17 | ........ | 7.00 | ........ | 6.28 | ........ | 4.96 | |
| ........ | .17 | 3.43 | ........ | 2.72 | ........ | 5.47 | ........ | |
| ........ | 10.00 | ........ | 2.75 | ........ | 7.11 | ........ | .71 | |
| ........ | 8.00 | ........ | 1.00 | ........ | 5.11 | 1.04 | ........ | |
| ........ | 4.00 | ........ | 4.00 | ........ | 1.11 | ........ | 1.96 | |
| 2.66 | ........ | ........ | 1.00 | 5.55 | ........ | 1.04 | ........ | |
| 11.66 | 34.78 | 3.43 | 19.75 | 20.16 | 20.16 | 8.59 | 8.59 | Mean vertical deviation from center of impact, 5′.04. |
| 23.12 ÷ 8 = 2.89 | | 16.32 ÷ 8 = 2.04 | | 40.32 ÷ 8 = 5.04 | | 17.18 ÷ 8 = 2.19 | | Mean horizontal deviation from center of impact, 2′.15. Mean deviation from center of impact, 5′.48. |
| 9.17 | ........ | ........ | 1.10 | 9.39 | ........ | ........ | 4.35 | Target No. 4.—Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards. |
| ........ | 6.00 | 1.25 | ........ | ........ | 5.78 | ........ | 2.00 | |
| ........ | 1.25 | 5.42 | ........ | ........ | 1.03 | 2.17 | ........ | |
| ........ | 4.10 | 3.25 | ........ | ........ | 3.88 | ........ | ........ | |
| 1.08 | ........ | 7.33 | ........ | 1.30 | ........ | 4.18 | ........ | |
| 10.25 | 11.35 | 17.25 | 1.10 | 10.69 | 10.69 | 6.35 | 6.35 | Mean vertical deviation from center of impact, 4′.28. |
| 1.10 ÷ 5 = .22 | | 16.15 ÷ 5 = 3.25 | | 21.38 ÷ 5 = 4.28 | | 12.70 ÷ 5 = 2.54 | | Mean horizontal deviation from center of impact, 2′.54. Mean deviation from center of impact, 4′.98. |

TABLE No. 1.—*Target record of firing with 3.20-inch breech-loading*

| | Number of fire. | Time. | Powder. Kind. | Powder. Wgt. Lbs. | Powder. Wgt. Oz. | Projectile. Kind. | | Projectile. Wgt. Lbs. | Projectile. Wgt. Oz. | Elevation in degrees. | Pressure, pounds per square inch of bore. | Instrumental velocity, taken 80' from muzzle. | Recoil, feet. | Direction of wind as regards line of fire. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1880. | | | | | | | | ° ′ | | *Feet.* | | |
| Barometer, 30.060; thermometer, 38; relative humidity, 47; wind, 2 miles an hour. | 192 | Nov. 19 | Du Pont's I. K. Density, 1.725; granulation, 2,200. | 2 | 8 | Hotchkiss, 1 copper band 1¼" wide, 95 per ct. copper, 5 per ct. spelter. Diameter across bands, 3".31; ribs, 3".14. | New shot. | 12 | .. | 3 35 | ...... | ...... | ... | From rear and left. |
| | 193 | Nov. 19 | | 2 | 8 | | Rebanded shell. | 12 | .. | 3 35 | ...... | ...... | ... | |
| | 194 | Nov. 19 | | 2 | 8 | | | 12 | .. | 3 35 | ...... | ...... | ... | |
| | 195 | Nov. 19 | | 2 | 8 | | | 12 | .. | 3 45 | ...... | ...... | ... | |
| | 196 | Nov. 19 | | 2 | 8 | | | 12 | .. | 3 50 | ...... | ...... | ... | |
| | 197 | Nov. 19 | | 2 | 8 | | New shell. | 12 | .. | 3 50 | ...... | ...... | ... | |
| | 198 | Nov. 19 | | 2 | 8 | | | 12 | .. | 3 50 | ...... | ...... | ... | |
| | 199 | Nov. 19 | | 2 | 8 | | | 12 | .. | 3 50 | ...... | ...... | ... | |
| | 200 | Nov. 19 | | 2 | 8 | | | 12 | .. | 3 50 | ...... | ...... | ... | |
| | 201 | Nov. 19 | | 2 | 8 | | | 12 | .. | 3 50 | ...... | ...... | ... | |
| | 202 | Nov. 19 | | 2 | 8 | | | 12 | .. | 3 50 | ...... | ...... | ... | |
| | 203 | Nov. 19 | | 2 | 8 | | | 12 | .. | 3 50 | ...... | ...... | ... | |
| | 204 | Nov. 19 | | 2 | 8 | Banded same as shell, new shot. | | 12 | .. | 3 50 | ...... | ...... | ... | |
| | 205 | Nov. 19 | | 2 | 8 | ....do .............. | | 12 | .. | 3 50 | ...... | ...... | .. | |
| | | 1881. | | | | | | | | | | | | |
| Barometer, 30.242; thermometer, 39; relative humidity, 73; wind, 2 miles an hour. | 206 | Feb. 11 | Du Pont's I. K. (A). Den., 1.725; gr., 2,200. | 2 | 8 | Hotchkiss, rebanded, 1 copper band, 95 per cent. copper, 5 per cent. spelter; 3 lands under band. | | 12 | .. | ½ | 23,000 | 1,377 | *30 | From right to left. |
| | 207 | Feb. 11 | | 2 | 8 | ....do .............. | | 12 | .. | ½ | 20,000 | Lost 90 *feet*. | 34 | |
| Barometer, 29.841; thermometer, 39; relative humidity, 100; wind, 24 miles an hour. | 208 | Mar. 9 | | 3 | .. | Hotchkiss (new), 1 copper band. | | 11 | 4 | ½ | 22,500 | 1,544 | 26 | From left to right. |
| | 209 | Mar. 9 | | 3 | .. | ....do .............. | | 11 | 5 | ½ | 21,000 | 1,522 | 26 | |
| | 210 | Mar. 9 | | 3 | .. | ....do .............. | | 11 | 4 | ½ | 22,500 | 1,542 | 26 | |
| | 211 | Mar. 9 | | 3 | .. | Butler (new) ........ | | 12 | .. | ½ | 15,000 | 1,313 | 26 | |
| | 212 | Mar. 9 | | 3 | .. | Hotchkiss, rebanded, 1 copper band. | | 12 | .. | ½ | 22,500 | 1,497 | 26 | |
| | 213 | Mar. 9 | | 3 | .. | Butler (new) ........ | | 12 | .. | ½ | 16,000 | 1,317 | 28 | |
| | 214 | Mar. 9 | | 3 | .. | Hotchkiss, rebanded, 1 copper band. | | 12 | .. | ½ | 22,500 | 1,494 | 28 | |

* On plank road.

***chambered rifle No. 774, at Sandy Hook, N. J.***—**Continued.**

| Diameter of projectile. | Length of projectile in calibers. | Number of ribs on shot. | Distance from center of target, in feet. Vertical. Above. | Below. | Horizontal. Right. | Left. | Distance from center of impact, in feet. Vertical. Above. | Below. | Horizontal. Right. | Left. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| " | | | | | | | | | | | |
| 3.18 | 2.8 | 5 | Fired at mile target; direct hit, 1' left, 1' above | | | | | | | | |
| 3.18 | 2.8 | 3 | Fired at mile target; sighting shots | | | | | | | | |
| 3.18 | 2.8 | 8 | | | | | | | | | |
| 3.18 | 2.8 | 8 | | | | | | | | | |
| 3.18 | 2.8 | 3 | 2.64 | | | 1.50 | .81 | | 3.17 | | Target No. 5.—Fired at mile target. Target 20' × 40', made of 1" spruce boards. |
| 3.18 | 2.8 | 3 | 2.00 | | | 6.33 | .17 | | | 1.06 | |
| 3.18 | 2.8 | 3 | 7.00 | | | 13.00 | 5.17 | | | 7.73 | |
| 3.18 | 2.8 | 3 | 5.00 | | | 9.00 | 3.17 | | | 3.73 | |
| 3.18 | 2.8 | 3 | | 3.00 | 7.42 | | | 4.83 | 12.69 | | |
| 3.18 | 2.8 | 3 | | 5.00 | | 16.25 | | 6.83 | | 10.98 | |
| 3.18 | 2.8 | 3 | 1.00 | | | 5.00 | | .83 | .27 | | |
| 3.18 | 2.8 | 3 | 5.00 | | 1.50 | | 3.17 | | 6.77 | | |
| | | | 22.64 | 8.00 | 8.92 | 51.08 | 12.49 | 12.49 | 23.50 | 23.50 | Mean vertical deviation from center of impact, 3'.12. |
| | | | 14.64 ÷ 8 = 1.83 | | 42.16 ÷ 8 = 5.27 | | 24.98 ÷ 8 = 3.12 | | 47.00 ÷ 8 = 5.87 | | Mean horizontal deviation from center of impact, 5'.87. Mean deviation from center of impact, 6'.65. |
| .... | 3 | 3 | Fired at mile target; over | | | | | | | | |
| .... | 3 | 3 | Fired at mile target; direct hit, 9'.50 above, 1' left | | | | | | | | |
| .... | .... | .... | Fired into sand butt to try powder | | | | | | | | |
| .... | .... | .... | | | | | | | | | |
| 3.18 | 2.8 | .... | Fired into sand butt to try powder. Projectiles in rounds 211 and 213 keyholed. | | | | | | | | At 210th round forward eye-belt holding right cap square over trunnion, and lower belt fastening left diagonal brace to axle, broke. Pressure gauge in breech-block; area of piston, 1 sq inch.; rectangular disc; circular knife. |
| 3.18 | 2.8 | .... | | | | | | | | | |
| 3.18 | 2.8 | .... | | | | | | | | | |
| 3.18 | 2.8 | .... | | | | | | | | | |
| 3.18 | 3 | .... | | | | | | | | | |
| 3.18 | 2.8 | .... | | | | | | | | | |
| 3.18 | 3 | .... | | | | | | | | | |

TABLE No. 2.—*Target record of firing with 3.20-inch breech-*

| | Number of fire. | Time. | Powder. Kind. | Powder. Wgt. Lbs. | Powder. Wgt. Oz. | Projectile. Kind. | Projectile. Wgt. Lbs. | Projectile. Wgt. Oz. | Elevation in degrees. | Pressure, pounds per square inch of bore. | Initial velocity, feet. | Recoil, feet. | Direction of wind as regards line of fire |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1881. | | | | | | | ° ′ | | | | |
| Proof rounds fired by the Constructor of Ordnance. | 1 | ........ | ............... | .. | .. | ............... | .. | .. | .... | ...... | ...... | ..... | |
| | 2 | ........ | ............... | .. | .. | ............... | .. | .. | .... | ...... | ...... | ..... | |
| Barometer, 29.612; thermometer, 41; relative humidity, 57 per cent.; wind, 23 miles an hour. | 3 | Mar. 24 | Du Pont's I. K. A. Density, 1.725; granulation, 2,200. | 3 | .. | Butler cored shot (new). Density, 3.18. | 12 | .. | .... | ...... | 1,452 | 26 | |
| | 4 | Mar. 24 | ....do ....... | 3 | .. | ....do ....... | 12 | .. | .... | ...... | 1,435 | 25.33 | |
| Barometer, 29.97; thermometer, 72; relative humidity, 54 per cent.; wind, 18 miles an hour. | 5 | June 15 | Du Pont's I. A. Density, 1.750; granulation, 2,200. | 2 | 8 | Butler cored shot. Diameter, 3.18; sabot long lip and flare. | 12 | .. | 0 | 13,500 | {1,268 1,270 1,272} | 22 | |
| | 6 | June 15 | Du Pont's I. K. A. Density, 1.725; granulation, 2,200. | 2 | 8 | ..do ....... | 12 | .. | −½ | 18,000 | {1,302 1,307 1,312} | 32 | |
| | 7 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | −½ | 17,000 | {1,280 1,292 1,304} | 21 | |
| | 8 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 30 | ...... | ...... | ..... | |
| | 9 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 45 | ...... | ...... | ..... | |
| | 10 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 50 | ...... | ...... | ..... | From rear and right. |
| | 11 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 50 | ...... | ...... | ..... | |
| | 12 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 50 | ...... | ...... | ..... | |
| | 13 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 50 | ...... | ...... | ..... | |
| | 14 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 50 | ...... | ...... | ..... | |
| | 15 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 50 | ...... | ...... | ..... | |
| | 16 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 50 | ...... | ...... | ..... | |
| | 17 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 50 | ...... | ...... | ..... | |
| | 18 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 50 | ...... | ...... | ..... | |
| | 19 | June 15 | ....do ....... | 2 | 8 | ....do ....... | 12 | .. | 1 50 | ...... | ...... | ..... | |

*loading chambered rifle No. 4, at Sandy Hook, N. J.*

| Length of projectile in calibers. | Distance from center of target, in feet. Vertical. Above. | Below. | Horizontal. Right. | Left. | Distance from center of impact, in feet. Vertical. Above. | Below. | Horizontal. Right. | Left. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| .... | ........ | | | | | | | | Gun mounted on new field carriage, steel axle. After proof rounds gun chambered for Butler sabot. |
| .... | ........ | | | | | | | | |
| 2.8 | Fired into sand butt; escape of gas; opened easily; outside lip of sabot at base expanded from 3″.31 to 3″.48 in firing. | | | | | | | | |
| 2.8 | Fired into sand butt; escape of gas; opened easily; gun and carriage free to recoil on plank road. | | | | | | | | |
| 2.5 | ........ | | | | | | | | |
| 2.5 | ........ | | | | | | | | |
| 2.8 | ........ | | | | | | | | |
| 2.5 | Fired at 1,000-yard target; sighting shots ........ | | | | | | | | Struck 80 yards short. |
| 2.5 | | | | | | | | | Passed under target. |
| 2.5 | ........ | 1.67 | ........ | 3.17 | ........ | 3.65 | ........ | 5.37 | Target No. 1.—Fired at 1,000-yd. target. Target 11′ × 52′, made of 1″ spruce boards. |
| 2.5 | 4.75 | ........ | ........ | 6.00 | 2.77 | ........ | ........ | 3.20 | |
| 2.5 | 4.83 | ........ | ........ | 6.17 | 2.85 | ........ | 1.63 | ........ | |
| 2.5 | 1.33 | ........ | 3.17 | ........ | ........ | .65 | 5.97 | ........ | |
| 2.5 | .66 | ........ | ........ | 1.83 | ........ | 1.32 | .97 | ........ | |
| | 11.57 | 1.67 | 3.17 | 17.17 | 5.62 | 5.62 | 8.57 | 8.57 | Mean vertical deviation from center of impact, 2′.25. Mean horizontal deviation from center of impact, 3′.43. Mean deviation from center of impact, 4′.10. |
| | 9.90÷5=1.98 | | 14.00÷5=2.80 | | 11.24÷5=2.25 | | 17.14÷5=3.43 | | |
| 2.8 | ........ | .83 | ........ | 2.58 | .05 | ........ | .54 | ........ | Target No. 2.—Fired at 1,000-yd. target. Target 11′ × 52′, made of 1″ spruce boards. |
| 2.8 | ........ | 4.25 | 1.15 | ........ | ........ | 3.37 | 4.27 | ........ | |
| 2.8 | .68 | ........ | ........ | 3.00 | 1.56 | ........ | .12 | ........ | |
| 2.8 | ........ | 1.50 | ........ | 8.00 | ........ | .62 | ........ | 4.88 | |
| 2.8 | 1.50 | ........ | ........ | 3.17 | 2.38 | ........ | ........ | .05 | |
| | 2.18 | 6.58 | 1.15 | 16.75 | 3.99 | 3.99 | 4.93 | 4.93 | Mean vertical deviation from center of impact, 1′.60. Mean horizontal deviation from center of impact, 1′.97. Mean deviation from center of impact, 2′.54. |
| | 4.40÷5=.88 | | 15.60÷5=3.12 | | 7.98÷5=1.60 | | 9.86÷5=1.97 | | |

**Table No. 2.**—*Target record of firing with* **3.20**-*inch breech-loading*

| | Number of fire. No. | Powder. Kind. | Powder. Wgt. Lbs. | Powder. Wgt. Oz. | Projectile. Kind. | Projectile. Wgt. Lbs. | Projectile. Wgt. Oz. | Elevation in degrees. | Pressure, pounds per square inch of bore. | Initial velocity, feet. | Recoil, feet. | Direction of wind as regards line of fire. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1881. | | | | | | | ° ′ | | | | |
| Barometer, 29.99; thermometer, 75; relative humidity, 40 per cent.; wind, 28 miles an hour. | 20 June 15 | Du Pont's I. K. A. Density, 1.725; granulation, 2,200. | 2 | 8 | Butler cored shot. Diameter, 3″.18; corrugated lip and flare. | 12 | .. | —¼ | 21,000 | 1,372 1,379 1,386 | 3.3 | From rear and right. |
| | 21 June 15 | | 2 | 8 | Butler cored shot. Diameter, 3″.18; short lip and flare. | 11 | 12 | —¼ | 17,000 | 1,293 1,301 1,309 | .... | |
| | 22 June 15 | | 2 | 8 | Butler cored shot. Diameter, 3″.18; corrugated lip and flare. | 12 | .. | 1 50 | ...... | ........ | .... | |
| | 23 June 15 | | 2 | 8 | ..do | 12 | .. | 1 50 | ...... | ........ | .... | |
| | 24 June 15 | | 2 | 8 | ....do | 12 | .. | 1 50 | ...... | ........ | .... | |
| | 25 June 15 | | 2 | 8 | ....do | 12 | .. | 1 40 | ...... | ........ | .... | |
| | 26 June 15 | | 2 | 8 | ....do | 12 | .. | 1 40 | ...... | ........ | .... | |
| | 27 June 15 | | 2 | 8 | ....do | 12 | .. | 1 40 | ...... | ........ | .... | |
| | 28 June 15 | | 2 | 8 | ....do | 12 | .. | 1 40 | ...... | ........ | .... | |
| | 29 June 15 | | 2 | 8 | ....do | 12 | .. | 1 40 | ...... | ........ | .... | |
| | 30 June 15 | | 2 | 8 | Butler cored shot. Diameter, 3″.18; short lip and flare. | 11 | 12 | 1 50 | ...... | ........ | .... | |
| | 31 June 15 | | 2 | 8 | ....do | 11 | 12 | 1 50 | ...... | ........ | .... | |
| | 32 June 15 | | 2 | 8 | ....do | 11 | 12 | 1 50 | ...... | ........ | .... | |
| | 33 June 15 | | 2 | 8 | ....do | 11 | 12 | 1 50 | ...... | ........ | .... | |
| | 34 June 15 | | 2 | 8 | ....do | 11 | 12 | 1 50 | ...... | ........ | .... | |
| Barometer, 29.77; thermometer, 73; relative humidity, 56 per cent.; wind, 14 miles an hour. | 35 June 21 | | 2 | 8 | Butler cored shot. Diameter, 3″.18; corrugated lip and flare. | 12 | .. | 1 40 | ...... | ........ | .... | From rear and left. |
| | 36 June 21 | | 2 | 8 | ....do | 12 | .. | 1 40 | ...... | ........ | .... | |
| | 37 June 21 | | 2 | 8 | ....do | 12 | .. | 1 40 | ...... | ........ | .... | |
| | 38 June 21 | | 2 | 8 | ....do | 12 | .. | 1 40 | ...... | ........ | .... | |
| | 39 June 21 | | 2 | 8 | ....do | 12 | .. | 1 40 | ...... | ........ | .... | |
| | 40 June 21 | | 2 | 8 | ....do | 12 | .. | 1 40 | ...... | ........ | .... | |

*chambered rifle No. 4, at Sandy Hook, N. J.*—Continued.

| Length of projectile in calibers. | Distance from center of target, in feet. Vertical. Above. | Distance from center of target, in feet. Vertical. Below. | Distance from center of target, in feet. Horizontal. Right. | Distance from center of target, in feet. Horizontal. Left. | Distance from center of impact, in feet. Vertical. Above. | Distance from center of impact, in feet. Vertical. Below. | Distance from center of impact, in feet. Horizontal. Right. | Distance from center of impact, in feet. Horizontal. Left. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 3 | | | | | | | | | |
| 3 | | | | | | | | | |
| 3 | | | | | | | | | |
| 3 | Fired at 1,000-yard target; sighting shots; over target | | | | | | | | |
| 3 | | | | | | | | | |
| 3 | 2.50 | | | 4.00 | 1.80 | | | .96 | Target No. 3.—Fired at 1,000-yd. target. Target 11′ × 52′, made of 1″ spruce boards. |
| 3 | | .50 | | 1.45 | | 1.20 | 1.59 | | |
| 3 | | 1.50 | | 2.60 | | 2.20 | .39 | | |
| 3 | 2.50 | | | 2.50 | 1.80 | | .54 | | |
| 3 | .50 | | | 4.60 | | .20 | | 1.56 | |
| | 5.50 | 2.00 | | 15.20 | 3.60 | 3.60 | 2.52 | 2.52 | Mean vertical deviation from center of impact, 1′.44. Mean horizontal deviation from center of impact, 1′.01. Mean deviation from center of impact, 1′.73. |
| | 3.50÷5=.70 | | 15.20÷5=3.04 | | 7.20÷5=1.44. | | 5.04÷5=1.01 | | |
| 3 | 4.35 | | | 3.00 | 2.84 | | .20 | | Target No. 4.—Fired at 1,000-yd. target. Target 11′ × 52′, made of 1″ spruce boards. Escape of gas at each round. From round 28 to 34, inclusive, breech-block did not open easily. |
| 3 | 1.00 | | | 1.50 | | .51 | 1.70 | | |
| 3 | | 1.15 | | 4.00 | | 2.66 | | .80 | |
| 3 | 1.35 | | | 4.00 | | .16 | | .80 | |
| 3 | 2.00 | | | 3.50 | .49 | | | .30 | |
| | 8.70 | 1.15 | | 16.00 | 3.33 | 3.33 | 1.90 | 1.90 | Mean vertical deviation from center of impact, 1′.33. Mean horizontal deviation from center of impact, 0′.76. Mean deviation from center of impact, 1′.53. |
| | 7.55÷5=1.51 | | 16.00÷5=3.20 | | 6.66÷5=1.33 | | 3.80÷5=.76 | | |
| 2.5 | | 4.00 | 1.00 | | | 3.71 | .19 | | Diagonal braces from inside of hub to cheeks of trail left off. Target No. 5.—Fired at 1,000-yd. target. Target 11′ × 52′ made of 1″ spruce boards. |
| 2.5 | | .32 | 1.43 | | | .03 | .62 | | |
| 2.5 | 1.50 | | | 1.00 | 1.79 | | | 1.81 | |
| 2.5 | .17 | | 2.25 | | .46 | | 1.44 | | |
| 2.5 | .58 | | 1.50 | | .87 | | .69 | | |
| 2.5 | .33 | | | .32 | .62 | | | 1.13 | |
| | 2.58 | 4.32 | 6.18 | 1.32 | 3.74 | 3.74 | 2.94 | 2.94 | Mean vertical deviation from center of impact, 1′.25. Mean horizontal deviation from center of impact, 0′.96. Mean deviation from center of impact, 1′.58. |
| | 1.74÷6=.29 | | 4.86÷6=.81 | | 7.48÷6=1.25 | | 5.88÷6=.96 | | |

TABLE No. 2.—*Target record of firing with 3.20-inch breech-loading*

| | Number of fire. | Time. | Powder. Kind. | Powder. Wgt. Lbs. | Powder. Wgt. Oz. | Projectile. Kind. | Projectile. Wgt. Lbs. | Projectile. Wgt. Oz. | Elevation in degrees. | Instrumental velocity taken 84' from gun. | Recoil, feet. | Direction of wind as regards line of fire. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1881. | | | | | | | ° ′ | *Feet.* | | |
| Barometer, 29.77; thermometer, 73; relative humidity, 56 per cent.; wind, 14 miles an | 41 | June 21 | Du Pont's I. K. A. Density, 1.725; granulation, 2,200. | 2 | 8 | Butler cored shot. Diameter, 3″.18; corrugated lip and flare. | 12 | .. | 1 40 | ........ | ...... | From rear and left. |
| | 42 | June 21 | | 2 | 8 | ......do ....... ........ | 12 | .. | 1 40 | ........ | ...... | |
| | 43 | June 21 | | 2 | 8 | ......do ................ | 12 | .. | 1 40 | ........ | ...... | |
| | 44 | June 21 | | 2 | 8 | ......do ................ | 12 | .. | 1 40 | ........ | ...... | |
| Barometer, 29.72; thermometer, 74; relative humidity, 49 per cent.; wind, 18 miles an hour. | 45 | June 21 | | 3 | .. | Butler cored shot. Diameter, 3″.18; long lip and flare. | 12 | .. | — 5 | 1,400<br>1,425<br>1,450 | 8.00 | |
| | 46 | June 21 | | 3 | .. | ......do ................ | 12 | .. | — 5 | 1,452<br>1,462<br>1,472 | 8.00 | |
| | 47 | June 21 | | 3 | .. | ......do ............ ... | 12 | .. | —10 | 1,408<br>1,421<br>1,434 | 8.00 | |
| | 48 | June 21 | | 3 | .. | ......do ................ | 12 | .. | —10 | 1,431<br>1,440<br>1,449 | 8.50 | |
| | 49 | June 21 | | 3 | .. | Butler cored shot. Diameter, 3.″18; short lip and flare. | 12 | .. | —10 | 1,454<br>1,465<br>1,476 | 8.00 | |
| | 50 | June 21 | | 3 | .. | ......do ................ | 12 | .. | —10 | 1,447<br>1,464<br>1,481 | 8.25 | |
| | 51 | June 21 | | 3 | . | ......do .......... ..... | 12 | .. | —10 | 1,440<br>1,455<br>1,470 | 8.25 | |
| | 52 | June 21 | | 3 | .. | ......do ................ | 12 | .. | —10 | ........ | 8.00 | |
| | 53 | June 21 | | 3 | .. | ......do ................ | 12 | .. | —10 | ........ | 10.00 | |
| | 54 | June 21 | | 3 | .. | ......do ............ ... | 12 | .. | —10 | ........ | 10.00 | |
| | 55 | June 21 | | 3 | .. | ......do ................ | 12 | .. | —10 | ........ | 10.00 | |
| | 56 | June 21 | | 3 | .. | ......do ................ | 12 | .. | —15 | ........ | 10.00 | |
| | 57 | June 21 | | 3 | .. | ......do ................ | 12 | .. | —15 | ........ | 10.00 | |
| | 58 | June 21 | | 3 | .. | ......do ................ | 12 | .. | —15 | ........ | 10.00 | |
| | 59 | June 21 | | 3 | .. | ......do ................ | 12 | .. | —15 | ........ | 10.00 | |
| | 60 | June 21 | | 3 | .. | ......do ................ | 12 | .. | —15 | ........ | 10.00 | |

*chambered rifle No. 4, at Sandy Hook, N. J.*—Continued.

| Length of projectile in calibers. | Distance from center of target, in feet. | | | | Distance from center of impact, in feet. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | Vertical. | | Horizontal. | | Vertical. | | Horizontal. | | |
| | Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. | |
| 2.8 | 1.00 | ........ | .17 | ........ | .92 | ........ | 1.13 | ........ | Target No. 6.—Fired at 1,000-yd. target. Target 11′ × 52′, made of 1″ spruce boards. |
| 2.8 | ........ | .68 | ........ | 1.75 | ........ | .76 | ........ | .79 | |
| 2.8 | ........ | 1.50 | ........ | .83 | ........ | 1.58 | .13 | ........ | |
| 2.8 | 1.50 | ........ | ........ | 1.43 | 1.42 | ........ | ........ | .47 | |
| | 2.50 | 2.18 | .17 | 4.01 | 2.34 | 2.34 | 1.26 | 1.26 | Mean vertical deviation from center of impact, 1′.17. Mean horizontal deviation from center of impact, 0′.63. Mean deviation from center of impact, 1′.63. |
| | .32÷4=.08 | | 3.84÷4=.96 | | 4.68÷4=1.17 | | 2.52÷4=.63 | | |
| 3.00 | Fired into sand butt to test carriage; carriage in sand from rounds 53 to 60, inclusive; board under trail. | | | | | | | | At round 51 steel axle was noticed to be bending backward and downward, and revolved half way round, so as to bring bottom of linch-pin on top. At round 44 elevating brace-pin broke. At round 36 clamp-spring, holding trail handspike to trail, spread. After round 60 bending of axle measured and found to be 0″.812. Axle straightened before further firing, and other repairs made to carriage, and a set-screw was tapped through plate holding right cheek to axle, to prevent axle from turning, and diagonal braces from inside of hub to cheeks of trail put on. |
| 3.00 | | | | | | | | | |
| 3.00 | | | | | | | | | |
| 3.00 | | | | | | | | | |
| 2.80 | | | | | | | | | |
| 2.80 | | | | | | | | | |
| 2.80 | | | | | | | | | |
| 2.80 | | | | | | | | | |
| 2.80 | | | | | | | | | |
| 2.80 | | | | | | | | | |
| 3.00 | | | | | | | | | |
| 2.50 | | | | | | | | | |
| 2.50 | | | | | | | | | |
| 2.50 | | | | | | | | | |
| 2.50 | | | | | | | | | |
| 2.50 | | | | | | | | | |

TABLE NO. 3.—*Target record of firing with 3.20-inch breech-*

| | Number of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs. | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs. | Projectile. Weight. Oz. | Elevation in degrees. | Instrumental velocity taken at 84 feet from muzzle. | Recoil, feet. | Direction of wind as regards line of fire. | Length of projectile in calibers. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1881. | | | | | | | ° ′ | *Feet.* | | | |
| Proof rounds fired by the Constructor of Ordnance. | 1 | ........ | ........ | ........ | ........ | ........ | | | | | | | .... |
| | 2 | ........ | ........ | ........ | ........ | ........ | | | | | | | .... |
| | 3 | June 22 | Du Pont's I. K. A. Density, 1.725; granulation, 2.200. | 2 | 8 | Hotchkiss cored shot. Diameter of shot, 3″.18; diameter of band, 3″.31. | 11 | 4 | 1 40 | ........ | ... | From rear and right. | 2.5 |
| | 4 | June 22 | | 2 | 8 | | 11 | 4 | 1 30 | ........ | ... | | 2.5 |
| | 5 | June 22 | | 2 | 8 | | 11 | 4 | 1 35 | ........ | ... | | 2.5 |
| | 6 | June 22 | | 2 | 8 | | 11 | 4 | 1 35 | ........ | .. | | 2.5 |
| | 7 | June 22 | | 2 | 8 | | 11 | 4 | 1 35 | ........ | ... | | 2.5 |
| | 8 | June 22 | | 2 | 8 | | 11 | 4 | 1 35 | ........ | ... | | 2.5 |
| | 9 | June 22 | | 2 | 8 | | 11 | 4 | 1 35 | ...... | ... | | 2.5 |
| | 10 | June 22 | | 2 | 8 | | 11 | 4 | 1 35 | ........ | ... | | 2.5 |
| | 11 | June 22 | | 2 | 8 | | 11 | 4 | 1 35 | ........ | ... | From rear and left. | 2.8 |
| Barometer, 29.94; thermometer, 63; relative humidity, 42 per cent.; wind, 6 miles an hour. | 12 | June 22 | | 2 | 8 | | 11 | 4 | 1 35 | ........ | ... | | 2.8 |
| | 13 | June 22 | | 2 | 8 | | 11 | 4 | 1 35 | ........ | ... | | 2.8 |
| | 14 | June 22 | | 2 | 8 | | 11 | 4 | 1 35 | ........ | ... | | 2.8 |
| | 15 | June 22 | | 3 | .... | | 11 | 4 | −10 | 1,534<br>1,545<br>1,556 | 8 | | 2.5 |
| | 16 | June 22 | | 3 | .... | Rebanded. | 12 | .... | −10 | 1,493<br>1,498<br>1,503 | 8 | | 3 |
| | 17 | June 22 | | 3 | .... | | 12 | .... | −10 | 1,479<br>1,497<br>1,515 | 8 | | 3 |
| | 18 | June 22 | | 3 | ... | | 12 | .... | −10 | 1,502<br>1,513<br>1,524 | 8 | | 2.8 |
| | 19 | June 22 | | 3 | .... | | 12 | .... | −10 | 1,488<br>1,503<br>1,518 | 8 | | 2.8 |
| | 20 | June 22 | | 3 | .... | | 12 | .... | −10 | 1,511<br>1,514<br>1,517 | 8 | | 2.8 |
| | 21 | June 22 | | 3 | .... | | 12 | ... | −10 | ........ | 10 | | 2.8 |
| | 22 | June 22 | | 3 | .. | | 12 | .... | −10 | ...... | 10 | | 2.8 |
| | 23 | June 22 | | 3 | .... | | 12 | .... | −10 | ........ | 10 | | 2.[illegible] |
| Barometer, 29.93; thermometer, 70; relative humidity, 43 per cent.; wind, 6 miles an hour. | 24 | June 22 | | 3 | .... | | 12 | .... | −10 | ........ | 10 | | 2.8 |
| | 25 | June 22 | | 3 | .... | | 12 | .... | −10 | ........ | 10 | From front & left. | 2.8 |
| | 26 | June 22 | | 3 | .... | | 12 | .... | −10 | ........ | 10 | | 2.8 |
| | 27 | June 22 | | 3 | .... | | 12 | .... | −15 | ........ | 10 | | 2.8 |
| | 28 | June 22 | | 3 | .... | | 12 | .... | −15 | ...... | 10 | | 2.8 |
| | 29 | June 22 | | | .... | | 12 | .... | −15 | ........ | 10 | | 2.8 |

*loading chambered rifle No. 3, at Sandy Hook, N. J.*

| Distance from center of target in feet. | | | | Distance from center of impact in feet. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Vertical. | | Horizontal. | | Vertical. | | Horizontal. | | |
| Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. | |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | Diagonal braces from inside of hub to cheeks of trail put on. |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | |
| Fired at 1,000-yard target; sighting shot; over | | | | | | | | |
| Target 11′ × 52′, made of 1″ spruce boards; 15 to 20 feet short | | | | | | | | |
| .34 | ........ | 3.75 | ........ | 1.67 | ........ | ........ | 1.78 | Target No. 1.—Fired at 1,000-yard target; target 11′ × 52′, made of 1″ spruce boards. |
| ........ | 3.00 | 6.50 | ........ | ........ | 1.67 | .97 | ........ | |
| .75 | ........ | 6.18 | ........ | 2.08 | ........ | .65 | ........ | |
| ........ | 2.57 | 6.33 | ........ | ........ | 1.24 | .80 | ........ | |
| ........ | 3.00 | 2.67 | ........ | ........ | 1.67 | ........ | 2.86 | |
| ........ | .50 | 7.75 | ........ | .83 | ........ | 2.22 | ........ | |
| 1.09 | 9.07 | 33.18 | ........ | 4.58 | 4.58 | 4.64 | 4.64 | Mean vertical deviation from center of impact, 1′.53. Mean horizontal deviation from center of impact, 1′.55. Mean deviation from center of impact, 2′.18. |
| 7.98 ÷ 6 = 1.33 | | 33.18 ÷ 6 = 5.53 | | 9.16 ÷ 6 = 1.53 | | 9.28 ÷ 6 = 1.55 | | |
| ........ | 1.83 | 6.75 | ........ | ........ | 1.56 | 2.98 | ........ | Target No. 2.—Fired at 1,000-yard target; target 11′ × 52′, made of 1″ spruce boards. |
| ........ | 3.17 | 5.00 | ........ | ........ | 2.90 | 1.23 | ........ | |
| 2.50 | ........ | 2.00 | ........ | 2.77 | ........ | ........ | 1.77 | |
| 1.42 | ........ | 1.33 | ........ | 1.69 | ........ | ........ | 2.44 | |
| 3.92 | 5.00 | 15.08 | ........ | 4.46 | 4.46 | 4.21 | 4.21 | Round 13.—Rear bolt, holding transome bed-plate to left cheek of carriage, broke. |
| 1.08 ÷ 4 = .27 | | 15.08 ÷ 4 = 3.77 | | 8.92 ÷ 4 = 2.23 | | 8.42 ÷ 4 = 2.11 | | Mean vertical deviation from center of impact, 2′.23. Mean horizontal deviation from center of impact, 2′.11. Mean deviation from center of impact, 3′.08. |
| Fired into sand butt | | | | | | | | Round 17.—All bolts holding trunnion bed-plate to cheek of carriage entirely broken off. Round 18.—Cap-square on right side of carriage bent upwards owing to bed-plate on other side being loose. After round 20 firing discontinued; bolts in bed-plate replaced. Round 21.—Pin holding braces for elevating-screw broke. Round 23.—Elevating screw-braces broken loose from elevating-screw; elevating-screw taken out and braces taken off and elevation afterwards given with a quoin. Axle was found to be bent backwards and upwards 0.34 of an inch after round 29. From rounds 16 to 29, inclusive, ¾ pound of sand put in shot to bring weight up to 12 pounds. |

TABLE No. 3.—*Target record of firing with 3.20-inch breech-*

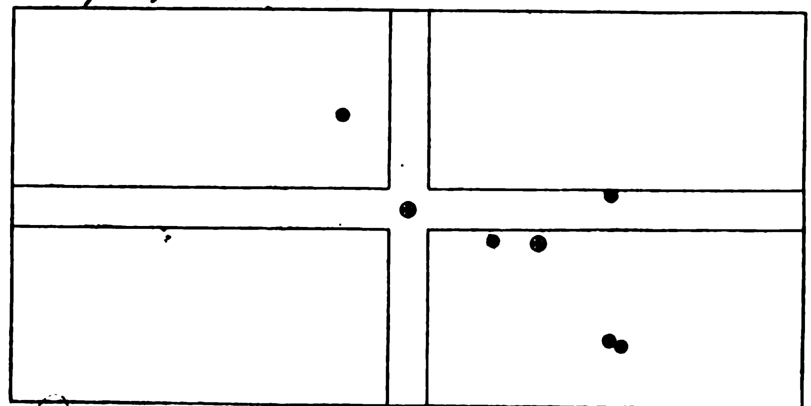
| | Number of fire. | Time. | Powder. | | | Projectile. | | | Elevation. | Direction of wind as regards line of fire. | Length of projectile in calibers. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Weight. | | Kind. | Weight. | | | | |
| | | | | Lbs | Oz. | | Lbs | Oz. | | | |
| Barometer, 30.15; thermometer, 71; relative humidity, 54 per cent.; wind, 7 miles an hour. | 30 | 1881. June 25 | Du Pont's I. K. A. Density, 1.725; granulation, 2,200. | 2 | 8 | Hotchkiss cored shot. Diameter, 3".18; diameter of band, 3".31. | 11 | 4 | 1° 35' | Front and left. | 2.5 |
| | 31 | June 25 | | 2 | 8 | | 11 | 4 | 1 30 | From left to right. | 2.5 |
| | 32 | June 25 | | 2 | 8 | | 11 | 4 | 1 30 | | 2.5 |
| | 33 | June 25 | | 2 | 8 | | 11 | 4 | 1 30 | | 2.5 |
| | 34 | June 25 | | 2 | 8 | | 11 | 4 | 1 30 | | 2.5 |
| | 35 | June 25 | | 2 | 8 | | 11 | 4 | 1 30 | | 2.5 |
| | 36 | June 25 | | 2 | 8 | | 11 | 4 | 1 30 | | 2.8 |
| | 37 | June 25 | | 2 | 8 | | 11 | 4 | 1 30 | | 2.8 |
| | 38 | June 25 | | 2 | 8 | | 11 | 4 | 1 30 | | 2.8 |
| | 39 | June 25 | | 2 | 8 | | 11 | 4 | 1 30 | | 2.8 |
| | 40 | June 25 | | 2 | 8 | | 11 | 4 | 1 30 | | 2.8 |
| Barometer, 29.61; thermometer, 85; relative humidity, 53 per cent.; wind, 10 miles an hour. | 41 | July 21 | | 2 | 8 | Hotchkiss (new); one copper band. | 11 | .... | 3 50 | From rear and right. | 2.8 |
| | 42 | July 21 | | 2 | 8 | | 11 | .... | 3 40 | | 2.8 |
| | 43 | July 21 | | 2 | 8 | | 11 | .... | 3 30 | | 2.8 |
| | 44 | July 21 | | 2 | 8 | | 11 | .... | 3 20 | | 2.8 |
| | 45 | July 21 | | 2 | 8 | | 11 | .... | 3 10 | | 2.8 |
| | 46 | July 21 | | 2 | 8 | | 11 | .... | 3 | | 2.8 |
| | 47 | July 21 | | 2 | 8 | | 11 | .... | 2 55 | | 2.8 |
| | 48 | July 21 | | 2 | 8 | | 11 | .... | 2 55 | | 2.8 |
| | 49 | July 21 | | 2 | 8 | | 11 | .... | 2 55 | | 2.8 |
| | 50 | July 21 | | 2 | 8 | | 11 | .... | 2 55 | | 2.8 |
| | 51 | July 21 | | 2 | 8 | | 11 | .... | 2 55 | | 2.8 |

*loading chambered rifle No* 3, *at Sandy Hook, N. J.*—Continued.

| Distance from center of target, in feet. | | | | Distance from center of impact, in feet. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Vertical. | | Horizontal. | | Vertical. | | Horizontal. | | |
| Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. | |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | Fired at 1,000-yard target; sighting shot; over. |
| ........ | 3.42 | 10.50 | ........ | ........ | 3.02 | 1.51 | ........ | Target No. 3.—Fired at 1,000-yard target. Target 11′ × 52′, made of 1″ spruce boards. |
| 2.00 | ........ | 8.66 | ........ | 2.40 | ........ | ........ | .31 | |
| 2.17 | ........ | 8.17 | ........ | 2.57 | ........ | ........ | .82 | |
| ........ | ........ | 9.43 | ........ | .40 | ........ | .44 | ........ | |
| ........ | 2.75 | 8.17 | ........ | ........ | 2.35 | ........ | .82 | |
| 4.17 | 6.17 | 44.95 | ........ | 5.37 | 5.37 | 1.95 | 1.95 | Mean vertical deviation from center of impact, 2′.15. Mean horizontal deviation from center of impact, 0′.78. Mean deviation from center of impact, 2′.29. |
| 2.00 ÷ 5 = .40 | | 44.95 ÷ 5 = 8.99 | | 10.74 ÷ 5 = 2.15 | | 3.90 ÷ 5 = .78 | | |
| ........ | ........ | 6.50 | ........ | .20 | ........ | .78 | ........ | Target No. 4.—Fired at 1,000-yard target. Target 11′ × 52′, made of 1″ spruce boards. |
| ........ | .08 | 5.58 | ........ | .12 | ........ | ........ | .14 | |
| ........ | .26 | 6.84 | ........ | ........ | .06 | 1.12 | ........ | |
| ........ | .08 | 4.68 | ........ | .12 | ........ | ........ | 1.04 | |
| ........ | .58 | 5.00 | ........ | ........ | .38 | ........ | .72 | |
| ........ | 1.00 | 28.60 | ........ | .44 | .44 | 1.90 | 1.90 | Mean vertical deviation from center of impact, 0′.18. Mean horizontal deviation from center of impact, 0′.76. Mean deviation from center of impact, 0′.78. |
| 1.00 ÷ 5 = .20 | | 28.60 ÷ 5 = 5.72 | | .88 ÷ 5 = .18 | | 3.80 ÷ 5 = .76 | | |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | Over target. Struck 200 yds. beyond. |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | Over target. Struck 150 yds. beyond. |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | Over target. Struck 100 yds. beyond. |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | Over target. Struck 100 yds. beyond. |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | Over target. Struck 75 yds. beyond. |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | Over target. Struck 50 yds. beyond. |
| ........ | 4.25 | 10.00 | ........ | .73 | ........ | .42 | ........ | Target No. 5.—Fired at 1-mile target. Target 20′ × 40′, made of 1-inch spruce boards. |
| ........ | 5.50 | 12.00 | ........ | ........ | .52 | 2.42 | ........ | |
| ........ | 5 | 8.16 | ........ | ........ | .2 | ........ | 1.42 | |
| Under target. | | ........ | ........ | ........ | ........ | ........ | ........ | |
| ........ | 5.17 | 8.16 | ........ | ........ | .19 | ........ | 1.42 | Fired in the presence and at the request of the Light Artillery Board. |
| ........ | 19.92 | 38.32 | ........ | .73 | .73 | 2.84 | 2.84 | Mean vertical deviation from center of impact, 0′.37. Mean horizontal deviation from center of impact, 1′.42. Mean deviation from center of impact, 1′.47. |
| 19.92 ÷ 4 = 4.98 | | 38.32 ÷ 4 = 9.58 | | 1.46 ÷ 4 = .37 | | 5.68 ÷ 4 = 1.42 | | |

Target Record of 3.20 inch B.L. Chambered Rifle Hotchkiss proj: 20 Cal. long
at Sandy Hook N.J. July 14th 1880.
Target One mile from gun

Number of shots fired 8. Which hits 5. missed 3.



● Point aimed at
● Center of impact
Target 20' x 40' made of 1" spruce boards.

Mean vertical deviation from center of impact 4.00'
Mean horizontal deviation from center of impact 4.84'
Mean deviation from center of impact 6.25'

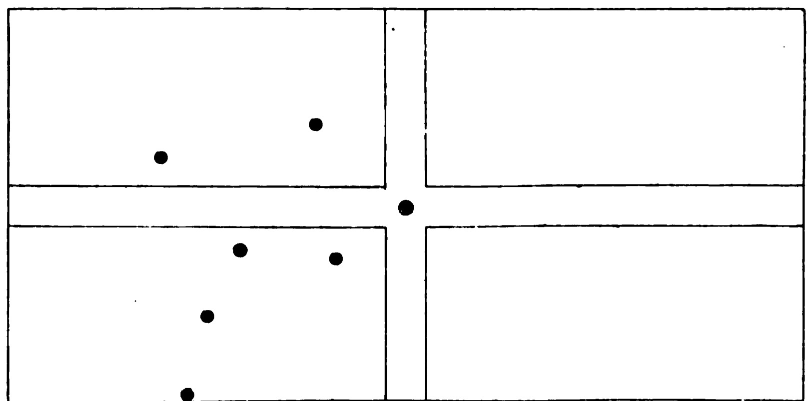
Wind 8 miles an hour

PLATE L.

Appendix 36?–1881.

Target Record of 3.20 inch B.L. Chambered Rifle Hotchkiss proj. 3.8 Cal. long
At Sandy Hook N.J. July 16th 1880
Target One Mile from Gun

Number of shots fired 10 — Direct Hits 5. Missed 5



● Center of impact
● Points struck at

Target 20' × 40' Made of 1" Spruce boards

Mean vertical deviation from center of impact 4.52
Mean longitudinal deviation from center of impact [illegible]
Mean deviation from center of impact 6.98

PLATE III.

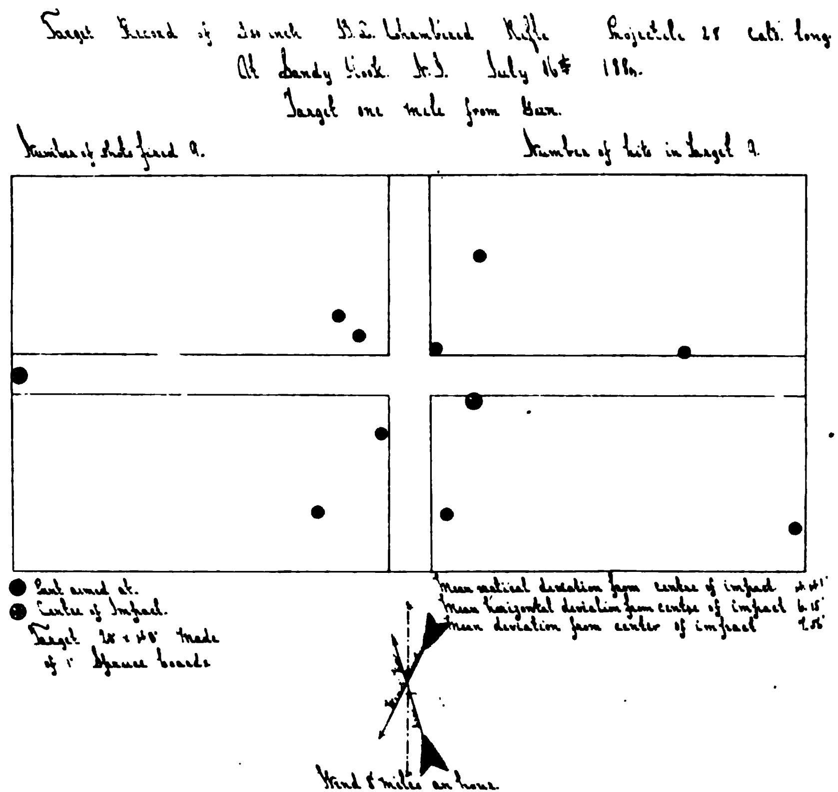
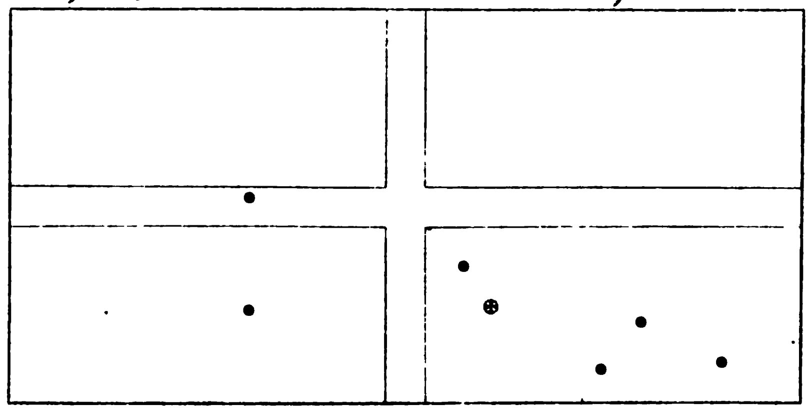

Target Record of inch Chambered Rifle Projectile cals. long
At Sandy Hook N.J. July 16th
Target one mile from Gun.
Number of shots fired 9.
Number of hits in target 9.
Point aimed at.
Center of Impact.
Target made of Spruce boards
Mean vertical deviation from center of impact
Mean horizontal deviation from center of impact 6.15'
Mean deviation from center of impact
Wind 8 miles an hour.

PLATE IV.

Target Record of 3.20 inch B.L. Chambered Rifle Projectile 2.5 calibres long
at Sandy Hook N.J. Sept. 2nd 1890
Target One mile from gun

Number of shots fired 6 No. of hits 6



⊕ Center of impact
Target 20' x 40' made of 1" spruce boards


Mean vertical deviation from center of impact 2.52
Mean horizontal deviation from center of impact 5.50
Mean deviation from center of impact 8.87

Wind 14 miles an hour

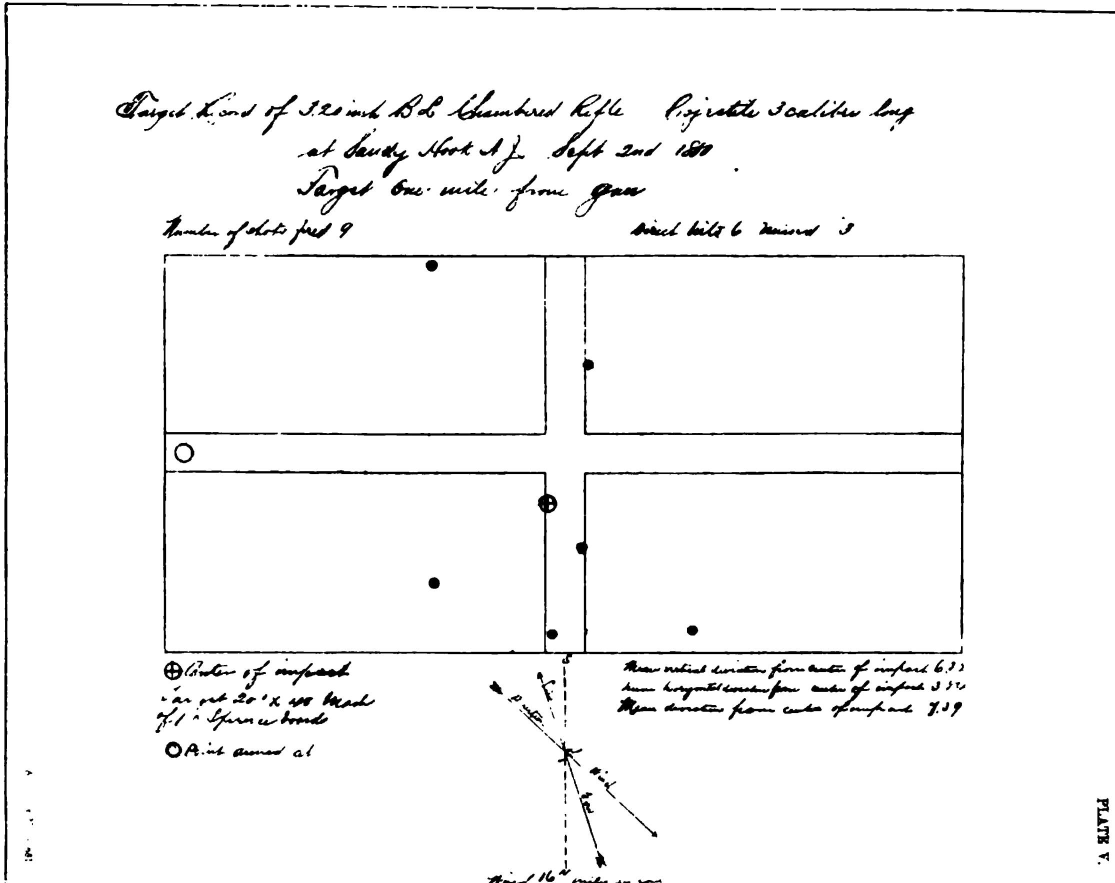
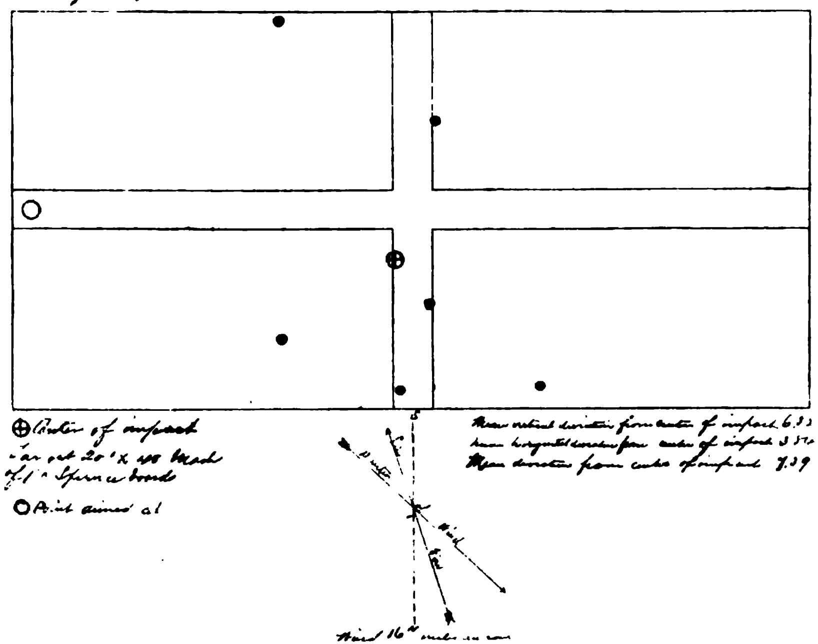

Target Record of 3.20 inch B.L. Chambered Rifle Projectile 3 caliber long
at Sandy Hook N.J. Sept 2nd 1880
Target One mile from Gun
Number of shots fired 9
Direct hits 6 missed 3
Center of impact
Target 20' x 40' Made of 1" Spruce boards
Point aimed at
Mean vertical deviation from center of impact 6.3?
Mean horizontal deviation from center of impact 3.3?
Mean deviation from center of impact 7.39
Wind 16 miles
Wind
Drift

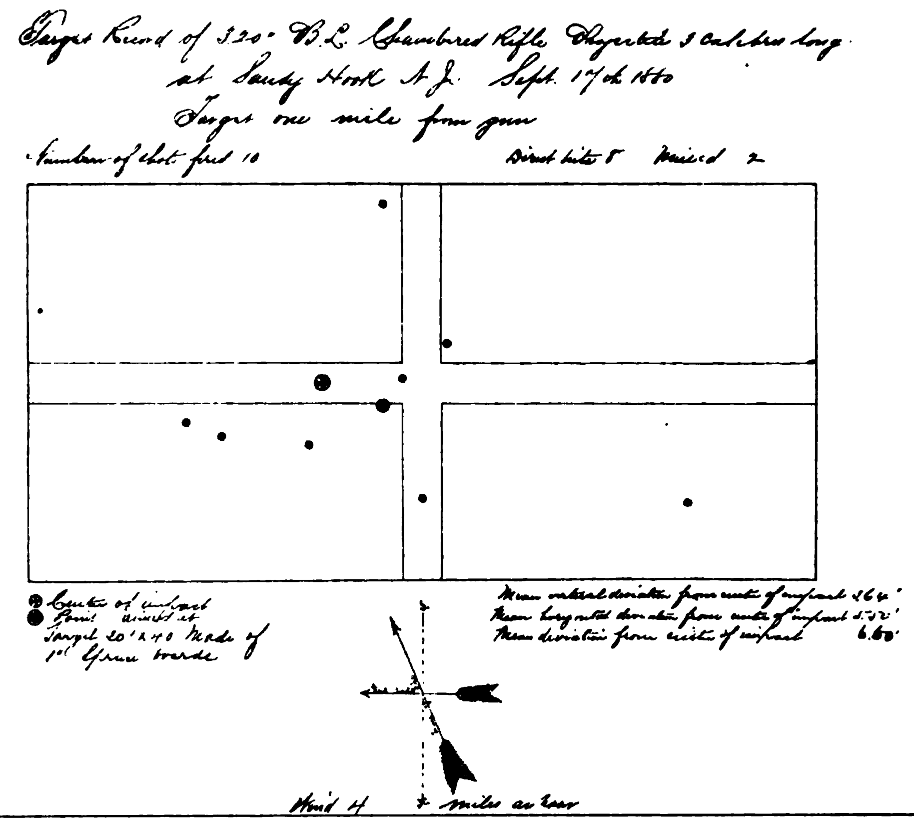
PLATE V.

Target Record of 3.20 inch B.L. Chambered Rifle. Projectile 3 calibres long
at Sandy Hook N.J. Sept 2nd 1880
Target One mile from Gun

Number of shots fired 9

Direct hits 6 Missed 3

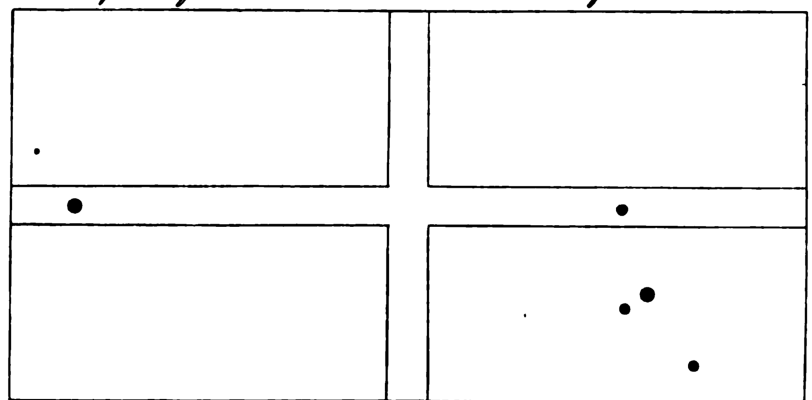



Target Record of 3.20" B.L. Chambered Rifle Projectile 3 Calibres long.
at Sandy Hook N.J. Sept. 17th 1880
Target one mile from gun
Number of shots fired 10
Direct hits 8 Missed 2
Centre of impact
Point aimed at
Target 20'×40' Made of 1" Pine boards
Mean vertical deviation from centre of impact 4.64'
Mean horizontal deviation from centre of impact 5.52'
Mean deviation from centre of impact 6.60'
Wind 4 miles an hour

#1

Target Record of 3.20 inch B. L. Chase Rifle #774 Hotchkiss proj: 3 calibres long
at Sandy Hook N. J. Nov 17th 1880
Target one mile from gun

Number of shots fired 3 Number of hits 3



● Center of impact
● Point aimed at
Target 20' x 40' made of
1" Spruce boards

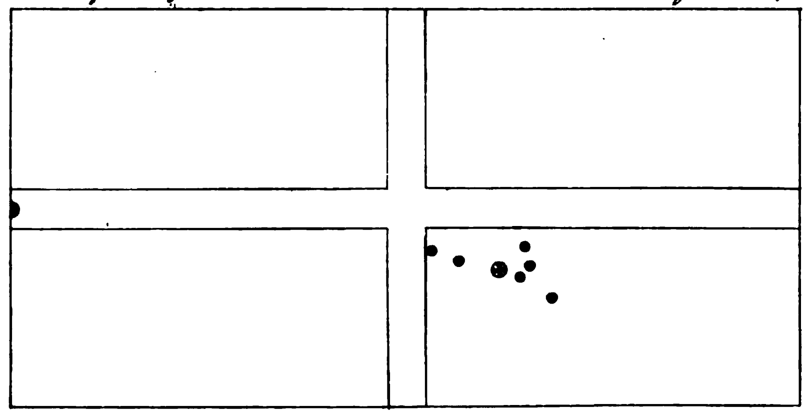
Wind 16 miles an hour

Mean vertical deviation from center of impact 2.87'
Mean lateral deviation from center of impact 1.58'
Mean deviation from center of impact 3.29'

#2

Target Record of 3.20" B.L. Cham. Rifle # 774 – Hotchkiss Proj. 3 Calibers long.
at Sandy Hook N.J. Nov. 17th 1880
Target one mile from gun

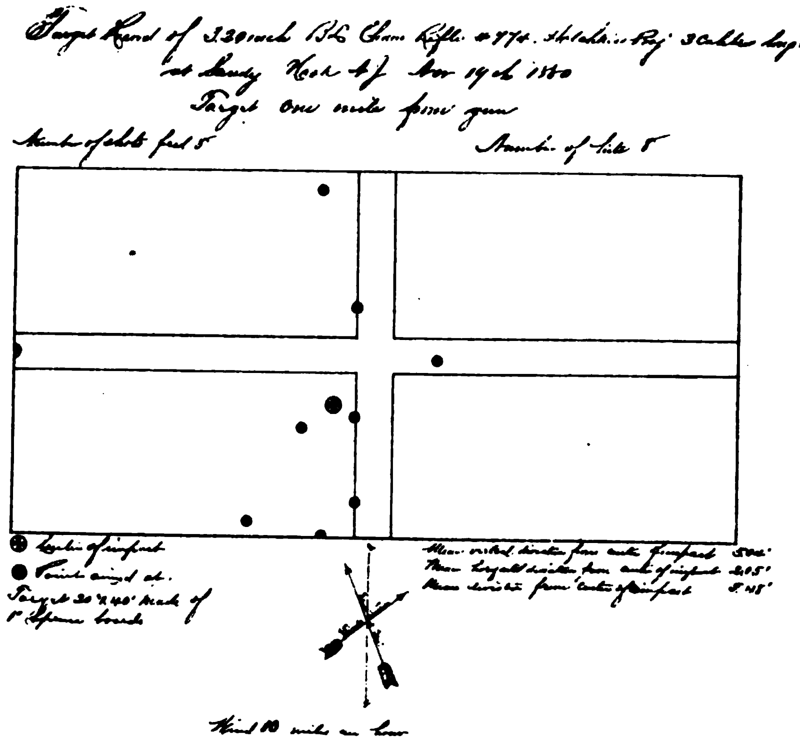
Number of shot fired 6 Number of hits 6.



Center of impact
Point aimed at
Target 20'x40' made of 1" Spruce board

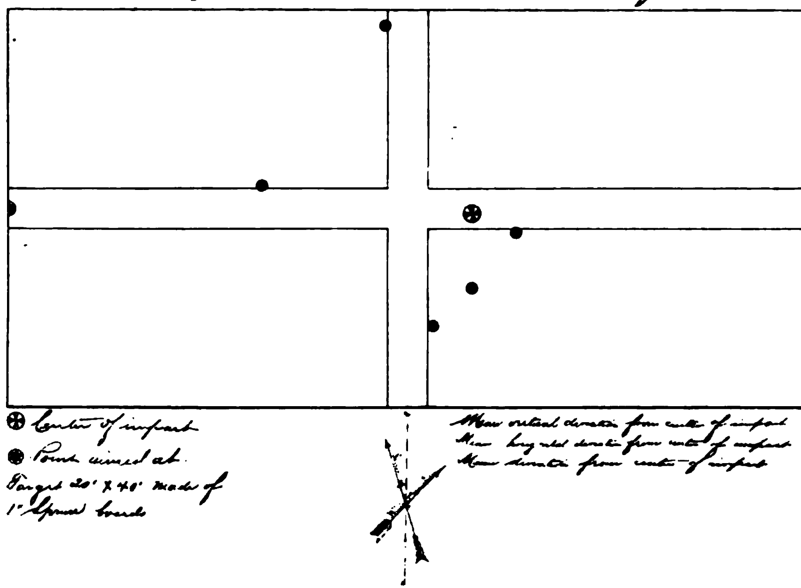
Mean vertical deviation from center of impact .75'
Mean horizontal deviation from center of impact 1.95'
Mean deviation from center of impact 2.09'

Wind 16 miles an hour.


Target Record of 3.20 inch B.L. Chain Rifle #774. Proj. 3 Calibres long.
at Sandy Hook N.J. Nov 19th 1880
Target One mile from gun
Number of shots fired 5
Number of hits 8
Centre of impact
Point aimed at.
Target 20' x 40' made of 1" Spruce boards
Mean vertical deviation from centre of impact 5.00'
Mean horizontal deviation from centre of impact 2.05'
Mean deviation from centre of impact 5.48'
Wind 10 miles an hour

Target Record of 3.2 inch B.L. Chamb. Rifle #774. Hotchkiss Proj. 2½ Calibre long
at Sandy Hook N.J. Nov 19th 1880
Target one mile from gun

Number of shots fired 5      Number of hits 5



⊕ Center of impact
● Point aimed at
Target 20' × 40' made of 1" Spruce boards

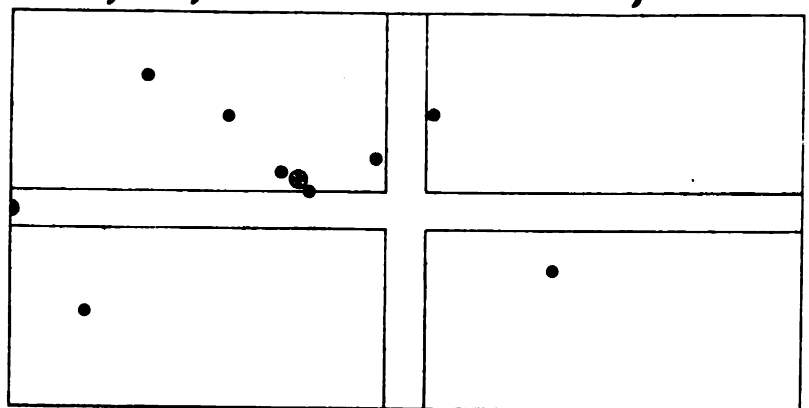
Mean vertical deviation from center of impact 4.28'
Mean longitudinal deviation from center of impact 2.07'
Mean deviation from center of impact 4.95

Wind 10 miles an hour

#-3

Target Record of 3.20 inch B.L. Chamber Rifle Hotchkiss Pg 25 Calibre long
at Sandy Hook N.J. Nov 19th 1880
Target one mile from gun

Number of shots fired 8 Number of hits 8



⊛ Centre of impact
● Point aimed at

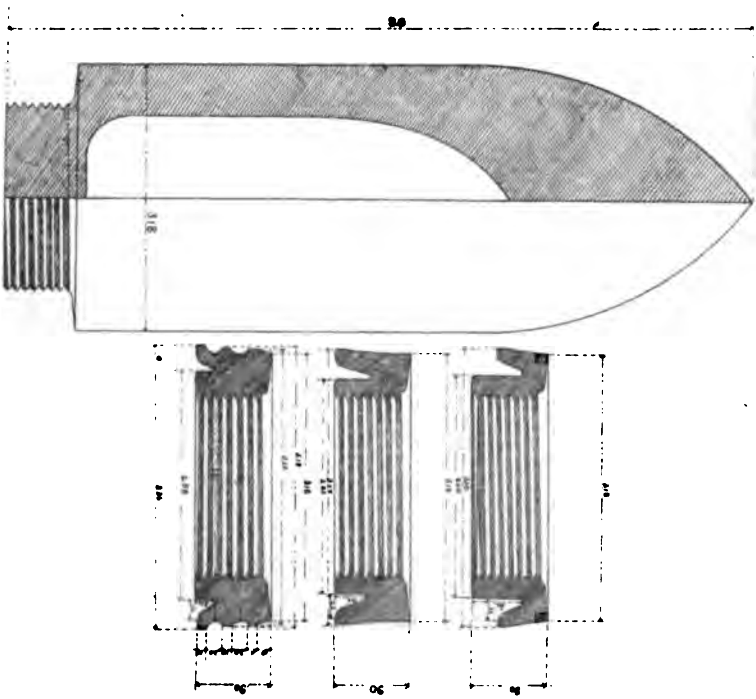
Target 20'×40' made of
1" Hemlock boards

Mean vertical deviation from centre of impact 3.12'
Mean horizontal deviation from centre of impact 5.87'
Mean deviation from centre of impact 6.65'

Wind 2 miles an hour

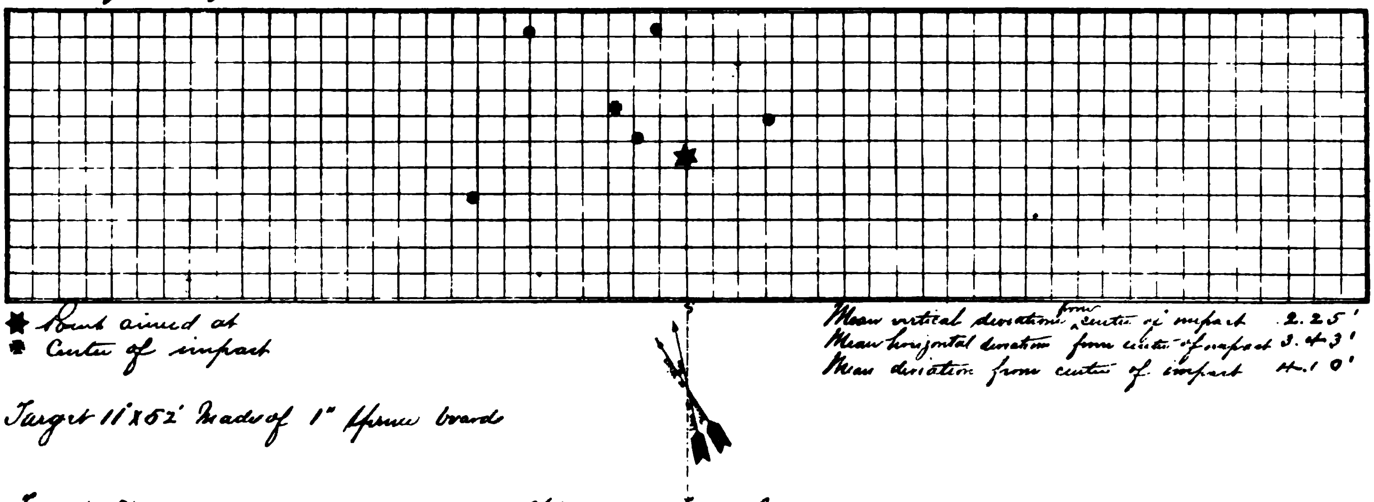
PLATE XI.

# BUTLER B.L.SHOT (320 lbs)



Target Record of 3.20 B L Chambered Rifle # 4. (Butler projectile) (long lst. bore. 2½ calibre)
at Sandy Hook N. J. June 15th 1881
Target 1000 Yards from gun.

Number of shots fired 5 Direct Hits 5



★ Point aimed at
✱ Center of impact

Mean vertical deviation from center of impact 2.25'
Mean horizontal deviation from center of impact 3.43'
Mean deviation from center of impact 4.10'

Target 11'x52' Made of 1" Spruce boards

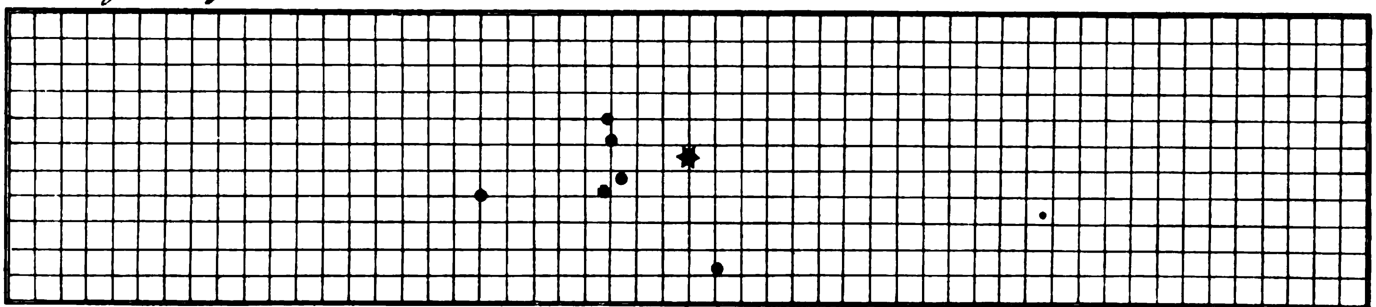
Target No. 1.

Wind 18 miles an hour

Target Record of 3.20 inch B. L. Chambered Rifle #4. (Butler projectile) (long lip sabot. 2½ calibres)
at Sandy Hook N. J. June 15th 1881
Target 1000 yards from gun

Number of shots fired 5

Direct Hits 5



★ Point aimed at
✱ Center of impact

Target 11' X 52' made of 1" Spruce boards

Mean vertical deviation from center of impact 1.60'
Mean horizontal deviation from center of impact 1.97'
Mean deviation from center of impact 2.54'

Target No. 2.

Appendix 38a—1881.

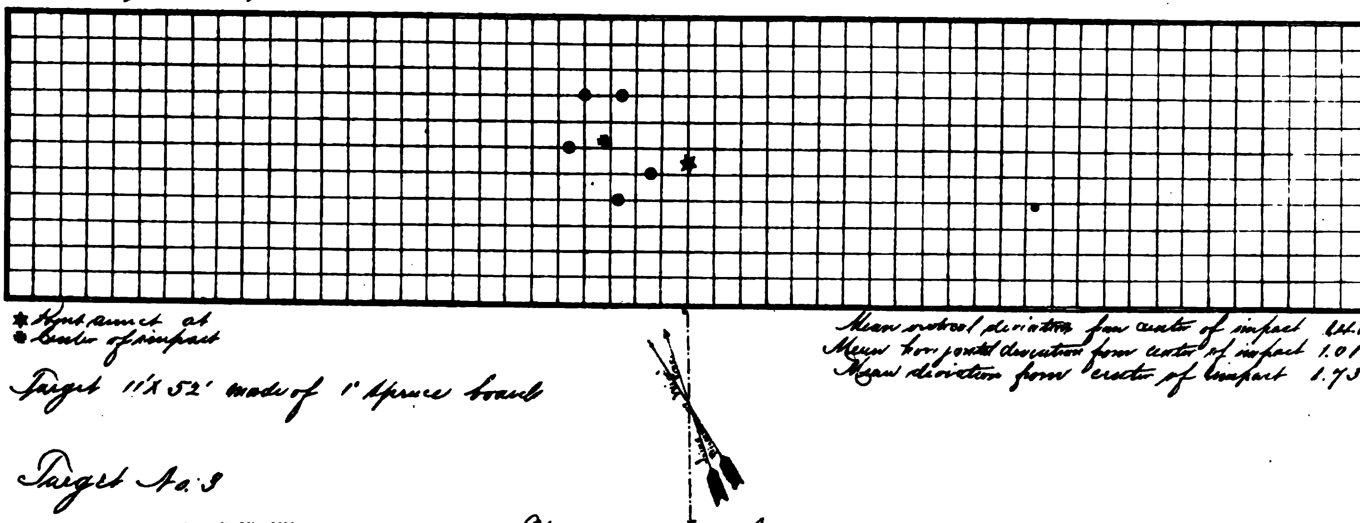
Wind 18 miles an hour.

PLATE XIV.

Target Record of 3.20 inch B. L. Chambered Rifle #4 (Butler projectile)
at Sandy Hook. N. J. June 15th 1881 (completed [illegible] calib. 3 calibers)
Target 1000 Yards from gun

Number of shots fired 5

Direct Hits 5



★ Point aimed at
● Centre of impact

Mean vertical deviation from centre of impact 1.40'
Mean horizontal deviation from centre of impact 1.01'
Mean deviation from centre of impact 1.73'

Target 11'x 52' made of 1" spruce board

Target No. 3

Wind 28 Miles an hour

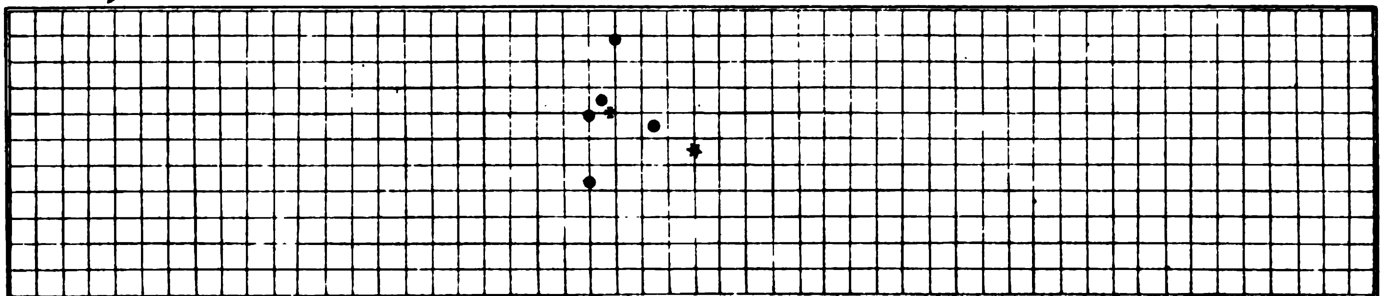
Appendix 38th—1881.

PLATE XV.

Target Record of 3.20 inch B. L. Chambered Rifle #4 (1 Butler projectile) (about [illegible]. 5 calibres)
at Sandy Hook N.J. June 15th 1881
Target 1000 Yards from gun

Number of shots fired 5

Direct Hits 5



* Point aimed at
● Centre of impact

Target 11'X52' Made of 1" Spruce boards

Target No 4

Wind 28 Miles an hour

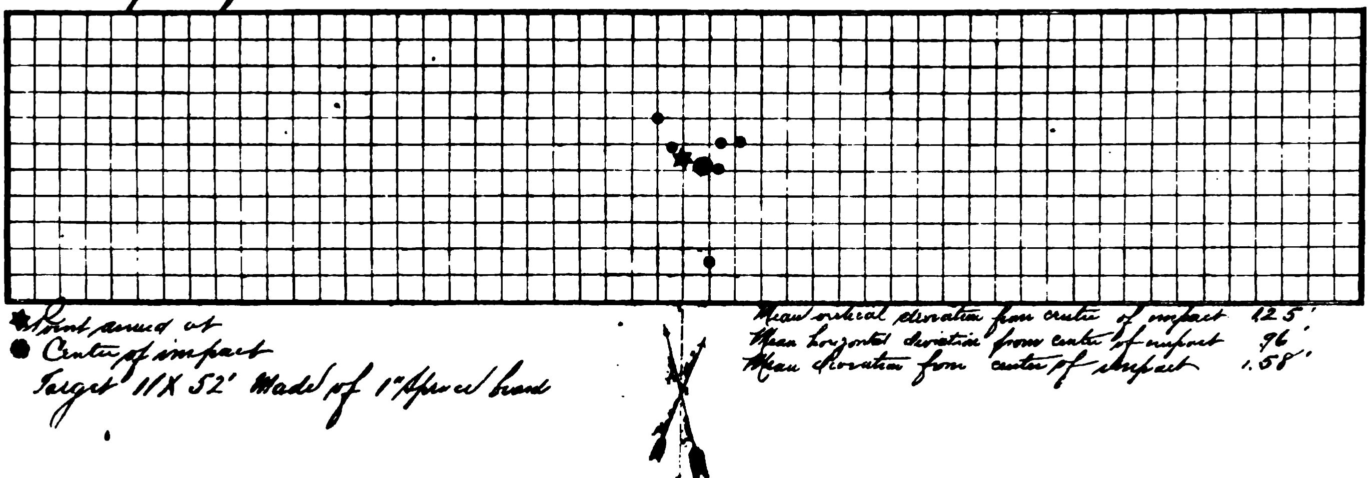
Mean vertical deviation from centre of impact 1.33'
Mean horizontal deviation from centre of impact .76'
Mean deviation from centre of impact 1.53'

PLATE XVI.

Target Record of 320 inch I. L. Rifle (chambered) #4 (1 Butler projectile 2½ calibre) (corrugated lip sabot)
at Sandy Hook. N.J. June 21st 1881
Target 1000 yards from gun

Number of shots fired 6

Direct hits 6



★ Point aimed at
● Center of impact
Target 11 X 52' Made of 1" Spruce board

Mean vertical deviation from center of impact 1.25'
Mean horizontal deviation from center of impact .96'
Mean deviation from center of impact 1.58'

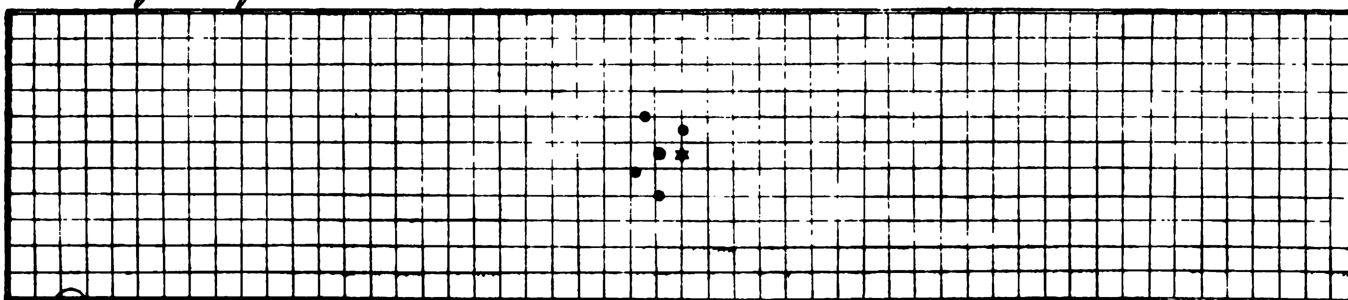
Target No 5

Appendix 30th—1881.

Wind 14 miles an hour

Target Record of 3.20 inch B. L. Rifle (chambered) # 4 (Butler projectile 2.8 calibres)
(compressed lip [illegible])
at Sandy Hook N. J. June 21st. 1881
Target 1000 Yards from gun

Number of shots fired 4 — Direct hits 4



✱ Point aimed at
● Centre of impact

Target 11' X 52' Made of 1" Spruce boards

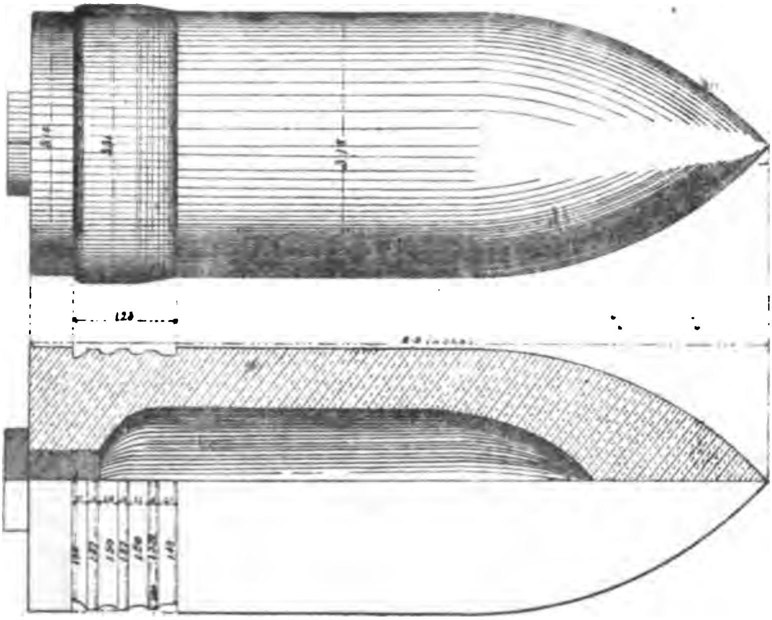
Mean vertical deviation from centre of impact 1.17'
Mean horizontal deviation from centre of impact .63'
Mean deviation from centre of impact 1.33'

Target No. 6.

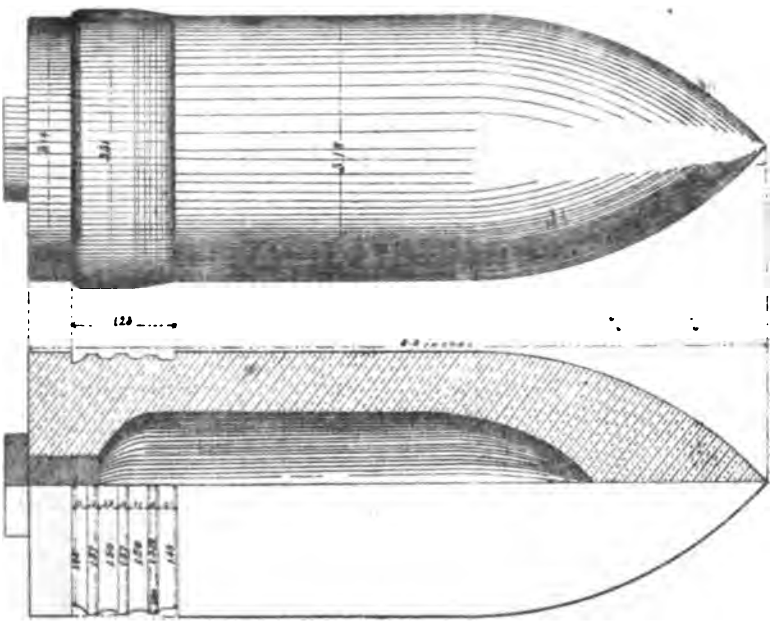
Wind 14 Miles an hour

PLATE XVIII.

# HOTCHKISS B.L. SHOT (820—)



# HOTCHKISS B.L. SHOT (820—)



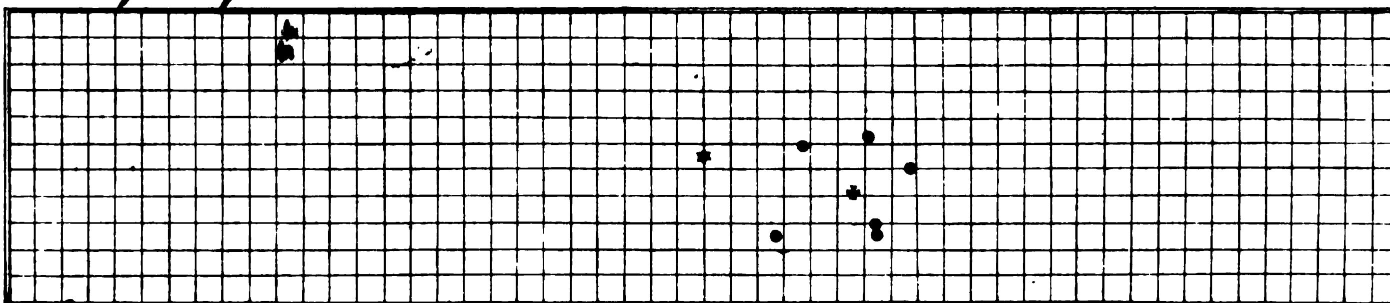
Appendix 88ᵇ—1561.

PLATE XX.

Target Record of 3.20 inch S.L. Rifle (chambered) #3 (Hotchkiss projectile) (2.5 Calibres)
at Sandy Hook N.J. June 22-1881
Target 1000 Yards from gun

Number of shots fired 6

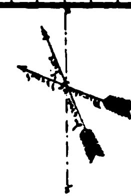
Number hits 6



* Point aimed at.
✚ Center of impact

Mean vertical deviation from center of impact 1.53'
Mean horizontal deviation from center of impact 1.55'
Mean deviation from center of impact 2.18'

Target 11'X52' made of 1" Spruce board



Target No 1.

Wind 6 miles an hour

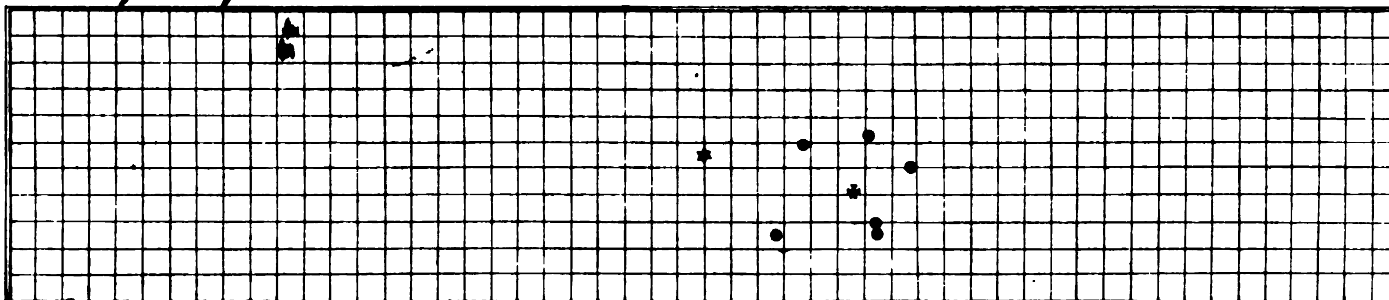
Appendix 35th—1881.

PLATE XX.

Target Record of 3.20 inch S. L. Rifle (chambered) #3 (Hotchkiss projectile) (2.5 Calibres)
at Sandy Hook N. J. June 22 - 1881
Target 1000 Yards from gun

Number of shots fired 6

Direct hits 6



* Point aimed at.
+ Center of impact

Target 11' X 52' made of 1" Spruce board

Mean vertical deviation from center of impact 1.53'
Mean horizontal deviation from center of impact 1.55'
Mean deviation from center of impact 2.18'

Target No 1.

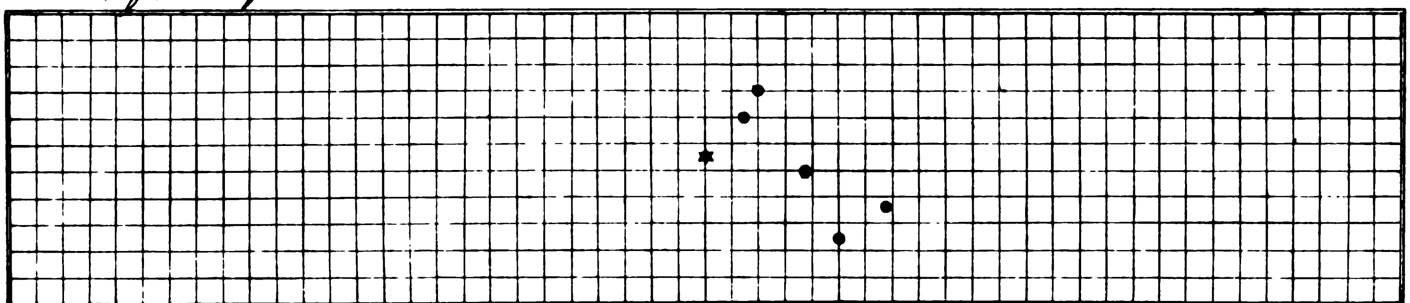
Wind 6 Miles an hour

PLATE XXI.

Target Record of 3.20 inch B. L. Rifle (chambered) #3 (Hotchkiss projectile) (28 Calibre)
at Sandy Hook N.J. June 22-1881
Target 1000 Yards from gun

Number of shots fired 4

Direct hits 4



★ Point aimed at
● Centre of impact

Target 11' X 52' made of 1" spruce board

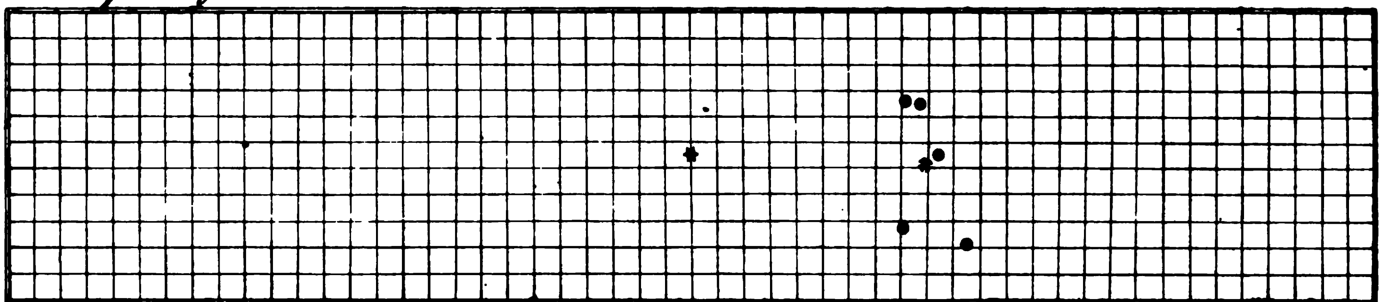
Mean vertical deviation from centre of impact 2.24'
Mean horizontal deviation from centre of impact 2.11'
Mean deviation from centre of impact 3.08'

Target No 2.

Wind 6 miles an hour

Target Record of 3.20 inch B. L. Gun bored Rifle No. 3. (Hotchkiss projectile 2.5 Calibre)
at Sandy Hook N. J. June 25th 1881.
Target 1000 Yards from gun.

Number of shots fired 5. Direct Hits 5.



✽ Point aimed at.
✽ Center of impact.

Target 11' X 52', made of 1" Spruce board.

Mean vertical deviation from center of impact. 2.15'
Mean horizontal deviation from center of impact. .78'
Mean deviation from center of impact. 2.29'

Target No 3.

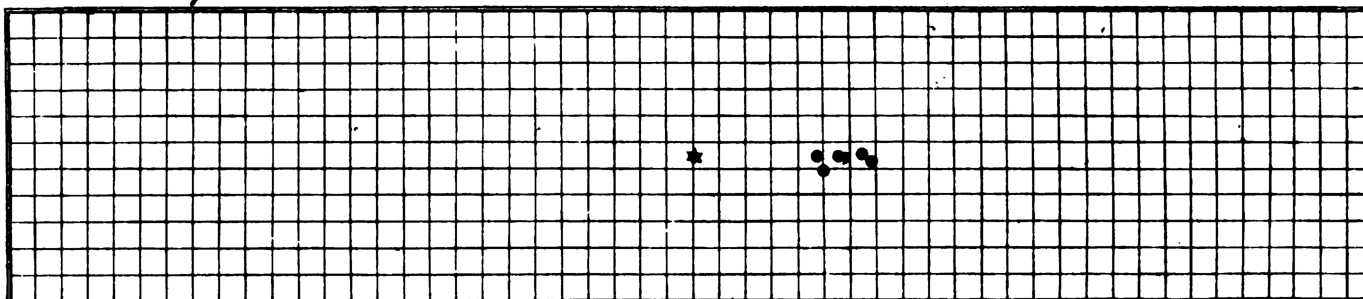
Wind 7 Miles an hour.

PLATE XXIII.

Target Record of 3.20 inch B. L. Chambered Rifle No. 3 (Hotchkiss projectile 2.8 calibers)
at Sandy Hook N. J. June 25th 1881
Target 1000 Yards from gun

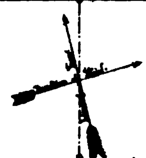
Number of shots fired 5

Direct Hits 5



* Point aimed at
* Center of impact
Target 11' X 52' made of 1" Spruce boards

Mean vertical deviation from center of impact .18'
Mean horizontal deviation from center of impact .76'
Mean deviation from center of impact .78'

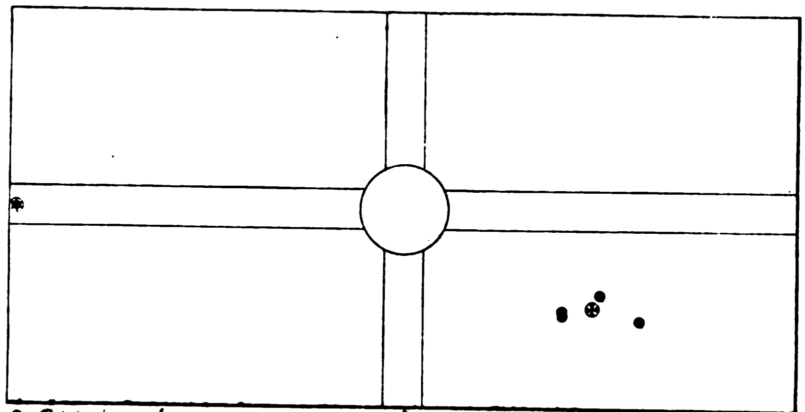


Target No 4.

Wind 7 miles an hour

Target Record of 3.2 inch B.L. Cham. Rifle No. 3. (Hotch. Ry. 28 cal.)
at Sandy Hook N.J. July 21st 1881
Target one mile from gun

Number of shots fired 5 Direct hits 4 Missed 1



● Point aimed at
⊕ Center of impact
Target 20' x 40' Made of
1" Spruce board

Mean vertical deviation from center of impact .37'
Mean horizontal deviation from center of impact 1.41'
Mean deviation from center of impact 1.46'

Target No 5

Wind 25 Miles an hour

# APPENDIX 38c.

## REPORT ON 11-INCH MUZZLE-LOADING CHAMBERED RIFLE No. 2.

(Three plates.)

A description in detail of this gun, a conversion from the 15″ smooth-bore, as originally turned over to the Ordnance Board for trial, will be found in this report. (Appendix 37a.)

### CARRIAGE.

The carriage from which this gun has been fired is the ordinary 15″ front-pintle, with pneumatic buffers, and the addition of a friction recoil check, as it was evident that with the use of the heavier projectiles and powder charges, as compared to those employed in the 15″ smooth-bore, the pneumatic buffers alone would not afford sufficient resistance to the recoil. The friction rail afforded the most economical auxiliary applicable to this purpose. After a few rounds it was found necessary to strengthen the check by increasing the rubber buffer at the rear, and by substituting a wrought for a cast-iron washer. Since then the carriage has worked well, considering its impromptu character.

### POWDERS.

The trial was begun with powder of the same type as that principally employed in the trial of the unchambered gun of this caliber, viz, Du Pont's Hexagonal I. H. A.; density, 1.8; granulation, 40; but the results with this powder, using charges of 120 pounds, for which the gun was first chambered, it will be seen, were not entirely satisfactory, and other powders were in turn tried, with the varying results shown in the accompanying table. Attention is especially invited to the varieties I. L., I. M., I. N., and I. O. The former, I. L., is the experimental powder submitted by Messrs. Du Pont, in which the percentage of nitre was reduced 5 per cent., and to which reference is made in the board's letter of February 8, 1881, given below. The varieties I. M., I. N., and I. O. were all of the same density and granulation (1.784—67), the only difference between them being in the mode of their manufacture. In the manufacture of the two lots, I. M. and I. N., the percentage of water employed in pressing was increased, and they differed further in manner of drying. In the lot I. O., the working in the incorporation mill was longer continued than is usual with powders of this type. The results with the I. O. were more uniform, and generally more satisfactory, and the test, with the approval of the department, will be completed with that make of powder.

### TEST OF THE GUN.

The gun, as turned over to the board, was chambered for a powder charge of 120 pounds, as shown in Plate I. After firing 22 rounds, with results as shown in the accompanying table, the board submitted the following communication to the department:

ORDNANCE BOARD,
*New York, February 8, 1881.*

The CHIEF OF ORDNANCE, U. S. A.,
*Washington, D. C.:*

SIR: I have the honor to inclose herewith an abstract from the firing record of the 11-inch chambered rifle, from the first to the last of the trial rounds thus far made. It will be seen that of the four varieties of powder tried, the F. P. C., density 1.785,

granulation 67, gave the most satisfactory results, with velocities and pressures gradually increasing up to a charge of 120 pounds, where an average velocity of 1,462.5 feet with a corresponding pressure of 36,750 pounds was obtained. An addition of 2½ pounds to the charge then gave but 5.5 feet increase in velocity, with a pressure running up to 41,000—indicating that with this powder, with the present sized chamber, a 120 pound charge would be about the limit.

The board, in considering these results, which, though fair for this conversion, do not entirely reach the power which it is thought should be realized from this gun, has carefully gone over the subjects of air-spacing and powders applicable to a gun of this class, when the subject of air-spacing is so pointedly met by shortness of bore, and from the reasons following is led to recommend an enlargement of the powder chamber to the proper dimensions for the accommodation of a powder charge of 130 pounds (F. P. C.) in lieu of the present 120. This enlargement can be given quickly, and at a little cost, by prolonging axially the present chamber 3′.33—simply moving the forward frustum that distance toward the muzzle. This method is considered preferable to a radial increase, as a diminution in thickness of that portion of the tube surrounding the chamber is thereby avoided. With this enlargement the capacity of the chamber is increased 377 cubic inches, giving a total capacity of 4,388 cubic inches, and an increase of 63 cubic inches in the total volume of bore; the space per pound of powder is increased to 33.75 cubic inches as compared to the present 33.42, while the number of volumes of expansion of the bore, with the ten pounds increase in charge, is diminished but 0.489. With this charge, still using the 550 pound shot, the calculated velocity, based upon the actual percentage realized in the trial of the present chamber—charge 120 pounds F. P. C.—will be 1,514 feet, with a corresponding pressure of 38,500 pounds, giving a total muzzle energy of 8,739.3 foot-tons, and a corresponding penetration of 19.6 inches—an increase of about 1¼ inches over that obtained with the present chamber. The necessary tools and fixtures for the enlargement of the chamber are on hand at the West Point Foundry, and by sending them to the Sandy Hook proving-ground the work can be done with the appliances and labor now there.

With regard to powders, it is proposed, in the event of this recommendation meeting with your approval, to continue the test with F. P. C., and, in addition, to experimentally test a new variety of hexagonal, granulation 67, density 1.75, proposed by the Messrs. Du Pont, in which the proportion of saltpeter used is to be 5 per cent. less than in the present standard, the slightly lower density being due to the replacement of the small proportion of niter by the lighter charcoal. This diminution in the percentage of niter should increase the amount of gas evolved and decrease that of the developed heat. By its use an increased velocity, without increase of pressure, may be theoretically anticipated, and an experiment made which may prove of value in the approaching trial of the 12 inch breech-loading rifles. Further, it may be said that the enlargement of the 11-inch chamber here proposed will be of decided importance in fixing the chamber dimensions of the 11-inch guns, both breech-loading and muzzle-loading, now in process of construction.

A tracing showing the relative dimensions of chambers for charges of 120, 125, and 130 pounds is herewith inclosed.

For the board.

Very respectfully, your obedient servant,

T. G. BAYLOR,
*Lieut. Col. of Ordnance, senior member present.*

This request meeting with the approval of the bureau, the chamber was enlarged as indicated, and the test of the gun resumed. The result of increasing the chamber capacity, it will be seen, was not such as the board had anticipated. The power of the gun was slightly increased, and the trial proceeded without especial incident up to round the 59th in all from the gun, the 47th using powder charges of 120 pounds and upwards, and the 37th after the enlargement of the chamber. At this stage of the trial the separation of a defective weld in the coiled tube occurred near the bottom of the chamber, the paper tube inserted in the gas-escape showing considerable escape of the powder gases. A series of impressions showed the opening to begin with the bottom coil at a point immediately in rear of the vent, and to extend almost completely around the tube, with a width varying from 0″.05 to 0″.075. Frequently taking impressions, the trial was continued to the 138th round, when firing was suspended awaiting the arrival of additional powder

and projectiles. The weld opening steadily, developed until it reached nearly three turns of the coil; the escape of gas, however, gradually diminished until it was scarcely observable.

The completion of this trial will be watched with great interest, as the present indications are that the tube will yield no further; but should it do so—should the welds at the bottom of the tube continue to yield spirally and the gun remain otherwise uninjured, and stand its test of 250 rounds, the inherent strength of the system will certainly have a crucial test under most adverse circumstances. Moreover the trial of the 11-inch breech-loader taking place at the same time, will afford a ready comparison between the behavior of the tubes in the two systems, muzzle and breech loading, where the attending circumstances differ in so obvious a manner.

Though the tube in this case has yielded to the longitudinal strains, the board is of the opinion that with the breech-loader when the rearward thrust is thrown almost entirely on the breech-block, the coiled tube will prove itself fully capable of filling the requirements for which it is intended and thus retain within the present resources of our own country the fabrication of interior tubes for our gun constructions of larger calibers.

TABLE No. 1.—*Record of firings for endurance with 11-inch muzzle-loading rifle*

DESCRIPTION OF GUN.—Rifle, converted from a 15-inch Rodman smooth-bored gun, by lining with a coiled, of bore, 11 inches; length of rifled bore, 120.037 inches; diameter of chamber, 12 inches; length of grooves, 0.09 inch; twist, uniform, one turn in 60 feet. Total length of gun, 201.367 inches; weight,

ORIGINAL

| Date. | Number of rounds. | Charge. Kind of powder. | Cartridge. Weight. | Cartridge. Height. | Cartridge. Diameter. |
|---|---|---|---|---|---|
| | | | *Lbs.* | *Ins.* | *Ins.* |
| January 12 | 1 | Du Pont's hexagonal, I. H. A. Density, 1.800; granulation, 40. | 80 | 25.55 | 10.367 |
| January 12 | 1 | ......do | 90 | 28.72 | 10.367 |
| January 12 | 1 | ......do | 100 | 31.90 | 10.367 |
| January 12 | 2 | ......do | 110 | 35.07 | 10.367 |
| January 12 | 2 | ......do | 115 | 36.66 | 10.367 |
| January 12 and 13 | 5 | ......do | 120 | 38.25 | 10.367 |
| January 13 | 1 | Du Pont's hexagonal, I. J. Density, 1.794; granulation, 30. | 125 | 39.90 | 10.367 |
| January 13 | 1 | Du Pont's hexagonal, F. P. C. Density, 1.785; granulation, 67. | 90 | 28.72 | 10.367 |
| January 13 | 1 | ......do | 100 | 31.90 | 10.367 |
| January 13 | 1 | ......do | 110 | 35.07 | 10.367 |
| January 13 and 18 | 2 | ......do | 115 | 36.66 | 10.367 |
| January 19 and 20 | 2 | ......do | 120 | 38.25 | 10.367 |
| January 22 | 1 | ......do | 122½ | 39.07 | 10.367 |
| January 22 | 1 | Du Pont's hexagonal, H. R. Density, 1.785; granulation, 50. | 120 | 38.25 | 10.367 |

ENLARGED

| Date. | Number of rounds. | Kind of powder. | Weight. | Height. | Diameter. |
|---|---|---|---|---|---|
| March 12, April 19, 20, 21, 26, 27, and 28, and May 7. | 51 | Du Pont's hexagonal, F. P. C. Density, 1.785; granulation, 67. | 125 | 39.90 | 10.367 |
| March 12 and 17 and April 19 and 20. | 5 | ......do | 127½ | 40.72 | 10.367 |
| March 12 and April 19 and 20 | 7 | ......do | 130 | 41.55 | 10.367 |
| March 15 and April 19, 28, and 29 | 5 | Du Pont's hexagonal, F. P. D. Density, 1.785; granulation, 67. | 125 | 39.90 | 10.367 |
| March 15 | 1 | ......do | 127½ | 40.72 | 10.367 |
| March 15 and April 29 | 15 | ......do | 130 | 41.55 | 10.367 |
| March 17 | 1 | Du Pont's hexagonal, I. L. Density, 1.750; granulation, 67. | 120 | 38.25 | 10.367 |
| March 17 | 1 | ......do | 125 | 39.90 | 10.367 |
| March 17 | 1 | ......do | 130 | 41.55 | 10.367 |
| March 17 | 1 | ......do | 135 | 43.20 | 10.367 |
| April 28 | 1 | Du Pont's hexagonal, I. H. A. Density, 1.800; granulation, 40. | 125 | 39.90 | 10.367 |
| April 28 | 1 | ......do | 130 | 41.55 | 10.367 |
| July 1 | 1 | Du Pont's hexagonal, I. P. Density, 1.765; granulation, 67. | 110 | 35.07 | 10.367 |
| July 1 | 1 | ......do | 115 | 36.66 | 10.367 |
| July 1 | 1 | ......do | 120 | 38.25 | 10.367 |
| July 1 | 1 | ......do | 125 | 39.90 | 10.367 |
| July 1 | 1 | ......do | 130 | 41.55 | 10.367 |
| May 19 | 1 | Du Pont's hexagonal, I. O. Density, 1.785; granulation, 67. | 120 | 38.25 | 10.367 |
| May 19 | 1 | ......do | 125 | 39.90 | 10.367 |
| May 19 and 27 | 5 | ......do | 130 | 41.55 | 10.367 |
| May 19 | 1 | Du Pont's hexagonal, I. M. Density, 1.785; granulation, 67. | 120 | 38.25 | 10.367 |
| May 19 | 1 | ......do | 125 | 39.90 | 10.367 |
| May 27 | 2 | ......do | 130 | 41.55 | 10.367 |
| May 19 | 1 | Du Pont's hexagonal, I. N. Density, 1.785; granulation, 67. | 120 | 38.25 | 10.367 |
| May 19 | 1 | ......do | 125 | 39.90 | 10.367 |
| May 19 and 27 | 3 | ......do | 130 | 41.55 | 10.367 |
| July 14 | 5 | Du Pont's hexagonal, F. P. D. Density, 1.785; granulation, 67. | 130 | 41.55 | 10.367 |
| Total | 138 | | | | |

*No. 2 (chambered), from January 12 to July 14, 1881, at Sandy Hook, N. J.*

wrought-iron tube, with a coiled, wrought-iron jacket shrunk on, inserted from the breech. Diameter chamber, including beveled portions, 11.58 inches; number of grooves and lands, 19 each; depth of 54,560 pounds.

CHAMBER.

| Projectile. Kind. | Projectile. Weight. | Projectile. Diameter. | Mean observed velocities of the projectile at 108 feet from the muzzle of the gun, as recorded by Le Boulengé's chronograph. | Velocities at the muzzle. | Velocities at 1,000 yards. | Muzzle energy. Total. | Muzzle energy. Per square inch of cross-section. | Muzzle energy. Per pound of powder. | Total energy at 1,000 yards. | Penetration. At muzzle. | Penetration. At 1,000 yards. | Gas pressure per square inch of bore, as taken with Rodman's internal pressure gauge. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Lbs.* | *Ins.* | *Feet.* | *Feet.* | *Feet.* | *Ft.-tons* | *Ft.-tons.* | *Ft.-tons.* | *Ft.-tons* | *Ins.* | *Ins.* | *Lbs.* |
| Butler. | 550 | 10.94 | 996 | | | | | | | | | 9,500 |
| ..do ... | 550 | 10.94 | 1,139 | | | | | | | | | 18,500 |
| ..do ... | 550 | 10.94 | 1,203 | 1,207 | 1,110.3 | 5,554.5 | 58.45 | 55.54 | 4,700.1 | 12.35 | 10.45 | 19,500 |
| ..do ... | 551 | 10.94 | 1,300 | | | | | | | | | 27,750 |
| ..do ... | 551 | 10.94 | 1,401 | | | | | | | | | 31,750 |
| ..do ... | 551 | 10.94 | 1,413 | 1,418 | 1,286.5 | 7,680.2 | 80.81 | 64.00 | 6.310.5 | 17.07 | 14.03 | 33,000 |
| ..do ... | 551 | 10.94 | 1,261 | | | | | | | | | 29,500 |
| ..do ... | 550 | 10.94 | 1,225 | | | | | | | | | 29,500 |
| ..do ... | 550 | 10.94 | 1,303 | 1,307 | 1,194.4 | 6,513.0 | 68.53 | 65.13 | 5,438.8 | 14.48 | 12.09 | 30,000 |
| ..do ... | 549 | 10.94 | 1,349 | | | | | | | | | 31,000 |
| ..do ... | 548 | 10.94 | 1,401 | | | | | | | | | 31,750 |
| ..do ... | 548 | 10.94 | 1,463 | 1,469 | 1,327.6 | 8,197.7 | 86.26 | 68.31 | 6,695.6 | 18.22 | 14.88 | 36,750 |
| ..do ... | 546 | 10.94 | 1,468 | | | | | | | | | 41,000 |
| ..do ... | 545 | 10.94 | 1,420 | | | | | | | | | 35,000 |

CHAMBER.

| Projectile. Kind. | Projectile. Weight. | Projectile. Diameter. | Mean observed velocities | Velocities at the muzzle. | Velocities at 1,000 yards. | Muzzle energy. Total. | Muzzle energy. Per square inch of cross-section. | Muzzle energy. Per pound of powder. | Total energy at 1,000 yards. | Penetration. At muzzle. | Penetration. At 1,000 yards. | Gas pressure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Butler. | 547 | 10.94 | 1,428 | | | | | | | | | 36,412 |
| ..do ... | 550 | 10.94 | 1,456 | | | | | | | | | 35,900 |
| ..do ... | 549 | 10.94 | 1,458 | 1,464 | 1,323.8 | 8,156.9 | 85.83 | 62.74 | 6,669.4 | 18.13 | 14.82 | 38,214 |
| ..do ... | 549 | 10.94 | 1,385 | | | | | | | | | 30,000 |
| ..do ... | 548 | 10.94 | 1,431 | | | | | | | | | 38,500 |
| ..do ... | 544 | 10.94 | 1,384 | 1,389 | 1,261.1 | 7,275.6 | 76.56 | 55.96 | 5,997.6 | 16.17 | 13.33 | 28,778 |
| ..do ... | 548 | 10.94 | 1,313 | 1,307.5 | 1,202.8 | 6,597.3 | 69.42 | 54.97 | 5.843.1 | 14.66 | 12.22 | 26,500 |
| ..do ... | 546 | 10.94 | 1,361 | 1,365.9 | 1,242.5 | 7,061.3 | 74.30 | 56.49 | 5,843.1 | 15.70 | 12.99 | 28,500 |
| ..do ... | 546 | 10.94 | 1,372 | 1,377 | 1,251.7 | 7,176.3 | 75.51 | 55.20 | 5,930.1 | 15.95 | 13.18 | 30,000 |
| ..do ... | 546 | 10.94 | 1,314 | | | | | | | | | 31,500 |
| ..do ... | 550 | 10.94 | 1,327 | | | | | | | | | 26,500 |
| ..do ... | 550 | 10.94 | 1,352 | 1,357 | 1,236 | 7,020.8 | 73.88 | 54.00 | 5,824.6 | 15.61 | 12.95 | 26,500 |
| ..do ... | 547 | 10.94 | 1,252 | | | | | | | | | 26,000 |
| ..do ... | 552 | 10.94 | 1,375 | | | | | | | | | 30,500 |
| ..do ... | 551 | 10.94 | 1,433 | 1,438.4 | 1,303.4 | 7,902.2 | 83.15 | 65.85 | 6,488.6 | 17.57 | 14.42 | 34,000 |
| ..do ... | 551 | 10.94 | 1,447 | 1,452.5 | 1,315.1 | 8,058 | 84.79 | 64.46 | 6,606.5 | 17.91 | 14.69 | 23,500 |
| ..do ... | 548 | 10.94 | 1,501 | 1,506.9 | 1,358.7 | 8,626.2 | 90.77 | 66.35 | 7,012.6 | 19.18 | 15.59 | 28,500 |
| ..do ... | 548 | 10.94 | *At 175 ft.* 1,409 | 1,417.4 | 1,285.4 | 7,632.4 | 80.31 | 63.60 | 6,276.9 | 16.97 | 13.95 | 35,500 |
| ..do ... | 547 | 10.94 | 1,451 | 1,460 | 1,320 | 8,082.5 | 85.05 | 64.66 | 6,607.5 | 17.97 | 14.69 | 36,000 |
| ..do ... | 546 | 10.94 | 1,471 | 1,480.2 | 1,336.5 | 8,293.2 | 87.26 | 63.79 | 6,760.1 | 18.44 | 15.03 | 29,900 |
| ..do ... | 548 | 10.94 | 1,350 | | | | | | | | | 32,000 |
| ..do ... | 547 | 10.94 | 1,374 | | | | | | | | | 32,000 |
| ..do ... | 544 | 10.94 | 1,389 | | | | | | | | | 24,250 |
| ..do ... | 548 | 10.94 | 1,396 | 1,404.3 | 1,274.7 | 7,491.3 | 78.82 | 62.42 | 6,172.1 | 16.65 | 13.72 | 35,000 |
| ..do ... | 547 | 10.94 | 1,424 | 1,432.6 | 1,297.7 | 7,782.6 | 81.89 | 62.26 | 6,385.4 | 17.30 | 14.19 | 34,000 |
| ..do ... | 546 | 10.94 | 1,464 | 1,473.1 | 1,330.3 | 8,214 | 86.43 | 63.18 | 6,607.5 | 18.26 | 14.89 | 30,833 |
| ..do ... | 553 | 10.94 | *At 109 ft.* 1,309 | | | | | | | | | 28,500 |

TABLE No. 2.—*Target record of firing with 11-inch muzzle-*

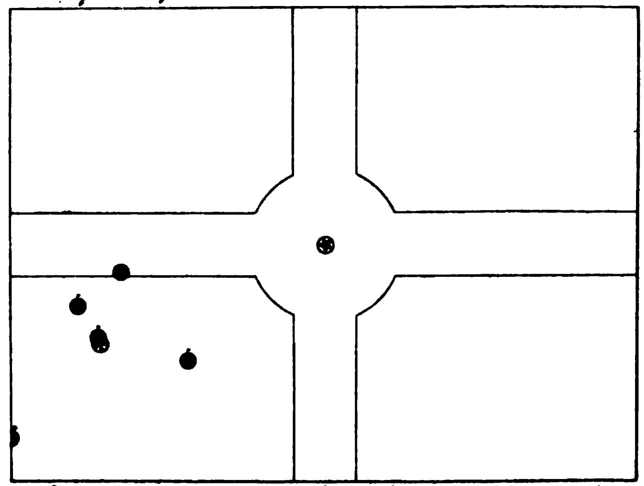
| | Number of fire. | Time. | Powder. Kind. | Powder. Lot. | Powder. Weight. Lbs. | Projectile. Kind. | Projectile. Weight. Lbs. | Elevation in degrees. ° ′ | Recoil, feet. | Direction of wind as regards line of fire. | Counter recoil, feet. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1881. | | | | | | | | | |
| Barometer, 29.97; thermometer, 63; relative humidity, 78 per cent.; wind, 6 miles an hour. | 78 | Apr. 28 | Du Pont's hexagonal, F. P. C. Density, 1.785; granulation, 67. | 2 | 125 | Butler, new. | 549 | 5 0 | 5.67 | From right to left. | .38 |
| | 79 | Apr. 28 | | 2 | 125 | ..do ... | 548 | 5 0 | 5.67 | From right to left. | .38 |
| | 80 | Apr. 28 | | 2 | 125 | ..do ... | 548 | 5 0 | 5.42 | From right to left. | .38 |
| | 81 | Apr. 28 | | 2 | 125 | ..do ... | 548 | 5 0 | 5.67 | From left to right | .38 |
| | 82 | Apr. 28 | | 3 | 125 | ..do ... | 547 | 5 0 | 5.50 | From left to right | .38 |
| Barometer, 29.97; thermometer, 69; relative humidity, 58 per cent.; wind, 10 miles an hour. | 85 | Apr. 28 | | 3 | 125 | Butler, new. | 547 | 5 2½ | 5.54 | From front and left. | .38 |
| | 86 | Apr. 28 | | 3 | 125 | ..do ... | 547 | 5 2½ | 5.58 | From front and left. | .36 |
| | 87 | Apr. 28 | | 3 | 125 | ..do ... | 546 | 5 5 | 5.42 | From front and left. | .38 |
| | 88 | Apr. 28 | | 3 | 125 | ..do ... | 546 | 5 5 | 5.42 | From front and left. | .38 |
| Barometer, 30.10; thermometer, 60; relative humidity, 62 per cent.; wind, 13 miles an hour. | 107 | May 7 | | 4 | 125 | Butler, new. | 545 | 5 5 | 6.20 | From front and left. | .38 |
| | 108 | May 7 | | 4 | 125 | ..do ... | 546 | 5 5 | 5.83 | From front and left. | .36 |
| | 109 | May 7 | | 4 | 125 | ..do ... | 546 | 5 5 | 5.23 | From front and left. | .39 |
| | 110 | May 7 | | 4 | 125 | ..do ... | 552 | 5 5 | 5.17 | From front and left. | .38 |
| | 111 | May 7 | | 4 | 125 | ..do ... | 552 | 5 5 | 5.00 | From front and left. | .28 |
| | 112 | May 7 | | 4 | 126 | ..do ... | 553 | 5 5 | 5.00 | From front and left. | .33 |

*loading rifle No. 2 (chambered), at Sandy Hook, N. J.*

| Distance from center of target, in feet. | | | | Distance from center of impact, in feet. | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Vertical. | | Horizontal. | | Vertical. | | Horizontal. | | |
| Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. | |
| | 4.00 | | 15.75 | 2.28 | | | 1.42 | Target No. 1.—Fired at 3,000-yard target. Target 30′ × 40′, made of 1″ spruce boards. Round 80, sabot stripped in flight; irregular. Round 82, slightly irregular flight. |
| | 1.75 | | 13.00 | 4.53 | | 1.33 | | |
| | 12.33 | | 19.75 | | 6.05 | | 5.42 | |
| | 6.00 | | 14.40 | .28 | | | .07 | |
| | 7.32 | | 8.75 | | 1.04 | 5.58 | | |
| | 31.40 | | 71.65 | 7.09 | 7.09 | 6.91 | 6.91 | Mean vertical deviation from center of impact, 2′.84. Mean horizontal deviation from center of impact, 2′.76. Mean deviation from center of impact, 3′.96. |
| 31.40 ÷ 5 = 6.28 | | 71.65 ÷ 5 = 14.33 | | 14.18 ÷ 5 = 2.84 | | 13.82 ÷ 5 = 2.76 | | |
| | 11.00 | 9.12 | | | 6.71 | 5.28 | | Target No. 2.—Fired at 3,000-yard target. Target 30′ × 40′, made of 1″ spruce boards. Round 85, flight fair. |
| | 4.50 | 1.50 | | | .21 | | 2.34 | |
| | 8.00 | | 1.00 | | 3.71 | | 4.84 | |
| 6.34 | | 5.74 | | 10.63 | | 1.90 | | |
| 6.34 | 28.50 | 16.36 | 1.00 | 10.63 | 10.63 | 7.18 | 7.18 | Mean vertical deviation from center of impact, 5′.31. Mean horizontal deviation from center of impact, 3′.59. Mean deviation from center of impact, 6′.41. |
| 17.16 ÷ 4 = 4.29 | | 15.36 ÷ 4 = 3.84 | | 21.26 ÷ 4 = 5.31 | | 14.36 ÷ 4 = 3.59 | | |
| | 2.50 | 5.83 | | .92 | | 2.83 | | Target No. 3.—Fired at 3,000-yard target. Target 30′ × 40′, made of 1″ spruce boards. Rounds 109, 110, 111, slightly irregular flight. |
| | 1.76 | 4.17 | | 1.70 | | 1.17 | | |
| Under | target | | | | | | | |
| | 12.00 | 3.83 | | | 8.54 | .83 | | |
| 10 feet | in front | of target | | | | | | |
| 2.42 | | | 1.83 | 5.88 | | | 4.83 | |
| 2.42 | 16.26 | 13.83 | 1.83 | 8.54 | 8.54 | 4.83 | 4.83 | Mean vertical deviation from center of impact, 4′.27. Mean horizontal deviation from center of impact, 2′.44. Mean deviation from center of impact, 4′.92. |
| 13.84 ÷ 4 = 3.46 | | 12.00 ÷ 4 = 3.00 | | 17.08 ÷ 4 = 4.27 | | 9.76 ÷ 4 = 2.44 | | |

Target Record of 11 inch M. L. Cham. Rifle No. 2 (Butler projectile)
at Sandy Hook N.J. April 28th 1881
Target 3000 yards from gun

Number of shots fired 5 · Direct hits 5



⊛ 1 Point aimed at
⊕ Center of impact
Target 30' x 40' made of 1" Spruce boards

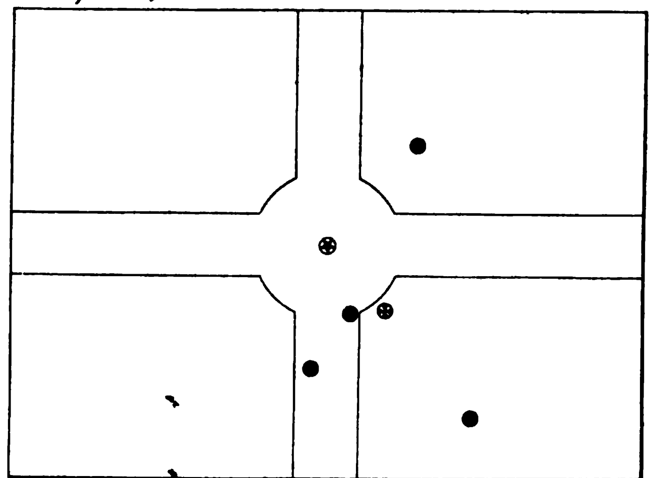
Wind 6 miles an hour

Mean vertical deviation from center of impact 2.90'
Mean horizontal deviation from center of impact 2.76'
Mean deviation from center of impact 3.96'

PLATE II.

Target Record of 11 inch M. L. Cham. Rifle No. 2 (Butler projectiles)
at Sandy Hook N. J. April 28th 1881
Target 3000 Yards from gun

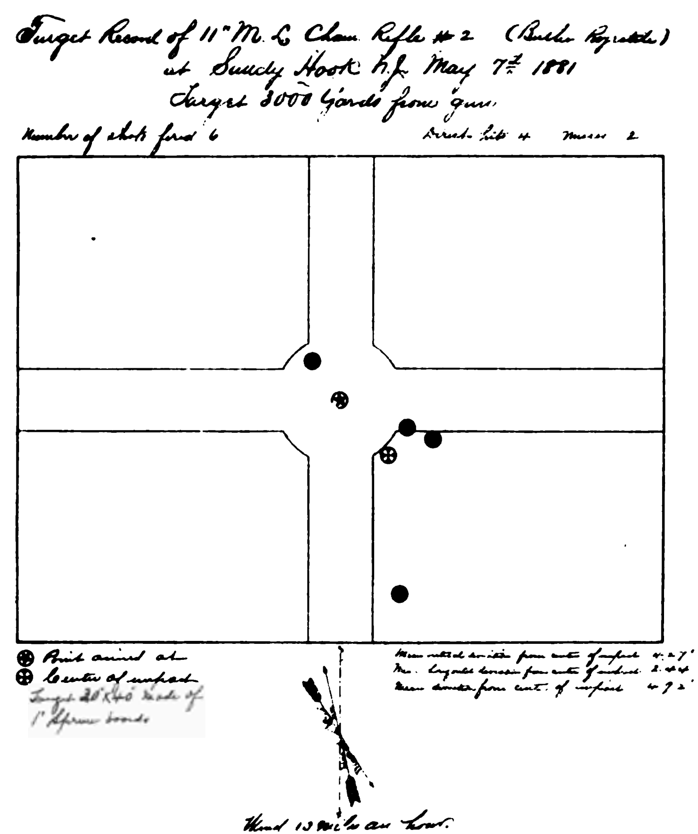
Number of shots fired 4 — Direct hits 4



⊛ Point aimed at
⊛ Centre of impact
Target 30' X 40' made of 1" Spruce boards

Mean vertical deviation from centre of impact 3.31'
Mean horizontal deviation from centre of impact 3.57'
Mean deviation from centre of impact 6.41'

Wind 10 miles an hour


Target Record of 11" M. L. Chan. Rifle #2 (Butler Projectile)
at Sandy Hook N.J. May 7th 1881
Target 3000 Yards from gun.
Number of shots fired 6
Direct hits 4
Misses 2
Point aimed at
Centre of impact
Target 20' x 40' made of 1" Spruce boards
Mean vertical deviation from centre of impact 4.27'
Mean lateral deviation from centre of impact 2.44
Mean deviation from centre of impact 4.92'
Wind 13 miles an hour.

# APPENDIX 38[d].

## REPORT OF TRIAL OF THE HOTCHKISS SHELLS WITH TRIPLE WALLS TO COMPARE THEM WITH THE COMMON HOTCHKISS WITH SINGLE WALLS.

[Three plates.]

The shells employed were the same in construction as those previously fired by the board, described in its report of April 29, 1879.

### FIRING RECORD.

Of 39 triple wall shells fired, 29 burst on first striking ground; 2 burst in air after first ricochet; 2 struck target and burst whilst passing through; 1 burst after passing through target; 1 burst at muzzle of gun; 2 broke up in gun, and 2 did not burst.

Of 29 common shells fired, 24 burst on first striking ground; 3 burst in air after first ricochet; 1 struck target and burst after passing through; 1 did not burst.

Comparing the target record of an equal number of shells of each kind, it is found that:

1st. Of 20 shells with triple walls 17 burst on striking ground in front of target; 2 ricochetted over target and burst beyond it, and 1 did not burst. From these projectiles 546 pieces hit the target; 398 pieces passing through, giving $32\frac{2}{17}$ hits per shell, $23\frac{7}{17}$ of which would have been effective against troops.

2d. Of 20 common shells, 17 burst on striking ground in front of target; 2 ricochetted over target and burst beyond, and 1 did not burst. From these projectiles 191 pieces hit the target; 172 pieces passing through, giving $11\frac{4}{17}$ hits per shell, $10\frac{2}{17}$ of which would have been effective.

Fourteen sighting shots were fired, using triple wall shells and new mortar powder, and it was of these that 1 burst at muzzle and 2 broke up in gun. With all the other kinds, I. K. A. powder was used and no premature explosions occurred.

### CONCLUSIONS.

On comparing the results of this series with those previously made by the board, it is found that all premature explosions of Hotchkiss shells of either kind occurred when the new mortar powder was employed, showing that none of these shells can be used safely with that powder, but that with the I. K. A. powder, which has given such excellent results in breech-loading field-pieces, they can be fired with safety.

All the trials have shown that the percussion fuze employed by Mr. Hotchkiss in these shells is not so sensitive or so regular in its action as is desirable for use in service.

In its effect, the triple-wall shell, though using a smaller bursting charge, proved to be fully twice as destructive as the common shell.

The board is of opinion that the triple-wall shell with an improved

fuze might be advantageously introduced into the field service, but since variations will occur in the strength of the charge used in the gun, it is advisable that this projectile be constructed to resist a heavier charge, and the board does recommend that the attention of Mr. Hotchkiss be called to the results obtained with his shells and fuzes, and that he be requested to have them so modified as to meet, if possible, the requirements of service.

*Target record of firing with 3.15 inches (8cm.) Hotchkiss breech loading rifle No. 787, at Sandy Hook, N. J.*

| | No. of fire. | Time. | Powder. | | | Projectile. | | | Elevation in degrees. | Length of projectile. | Bursting charge. | Direction of wind as regards line of fire. | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Weight. | | Kind. | Weight. | | | | | | | |
| | | | | Lbs. | Ozs. | | Lbs. | Ozs. | ° ′ | In. | Oz. | | | |
| Barometer, 30.32; thermometer, 57; relative humidity, 66 per cent.; wind, 8 miles an hour. | 126 | 1881. May 5 | New mortar | 2 | 8 | Hotchkiss triple-wall shell, two brass bands, Hotchkiss percussion fuse. | 12 | 4⅛ | —15 | 9⅛ | 4⅛ | From front and left. | Sighting shots to determine elevation for 500-yard target. | 240′ short; burst on striking. |
| | 127 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | — 8 | 9⅛ | 4⅛ | | | 105′ short; burst on striking. |
| | 128 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | — 5 | 9⅛ | 4⅛ | | | 105′ short; burst on striking. |
| | 129 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | 0 | 9⅛ | 4⅛ | | | Direct hit; burst going through target. |
| | 130 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | 0 | 9⅛ | 4⅛ | | | 71′ short; did not burst. |
| | 131 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | 0 | 9⅛ | 4⅛ | | | Burst at muzzle. |
| | 132 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | 0 | 9⅛ | 4⅛ | | | Direct hit 4′ right, 5′ below; burst going through target. |
| | 133 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | — 5 | 9⅛ | 4⅛ | | | 150′ short; burst on striking. |
| | 134 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | — 2⅛ | 9⅛ | 4⅛ | | | 180′ short; burst on striking. |
| | 135 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | — 2⅛ | 9⅛ | 4⅛ | | | Broke up in gun. |
| | 136 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | — 2⅛ | 9⅛ | 4⅛ | | | Broke up in gun. |
| | 137 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | — 2⅛ | 9⅛ | 4⅛ | | | 150′ short; burst on striking. |
| | 138 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | 0 | 9⅛ | 4⅛ | | | 120′ short; burst on striking. |
| | 139 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | 0 | 9⅛ | 4⅛ | | | 30′ short; burst on striking. |
| Barometer, 30.31; thermometer, 54; relative humidity, 74 per cent.; wind, 10 miles an hour. | 140 | May 5 | Du Pont's L. K. A.; density, 1.725; granulation, 2,200. | 2 | 8 | do | 12 | 4⅛ | 0 | 9⅛ | 4⅛ | | | Direct hit 5′ below, 2′ right; burst behind target. |
| | 141 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | —15 | 9⅛ | 4⅛ | | | 255′ short; burst on striking. |
| | 142 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | — 5 | 9⅛ | 4⅛ | | | 75′ short; burst on striking. |
| | 143 | May 5 | do | 2 | 8 | do | 12 | 4⅛ | — 5 | 9⅛ | 4⅛ | | | 60′ short; burst on striking. |

*Target record of firing with 3.15 inches (8cm.) Hotchkiss breech-loading rifle No. 787, at Sandy Hook, N. J.*—Continued.

| | No. of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs. | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs. | Projectile. Weight. Oz. | Elevation in degrees. | Length of projectile. | Bursting charge. | Direction of wind as regards line of fire. | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | ° ′ | *In.* | *Oz.* | | | |
| Barometer, 30.31; thermometer, 54; relative humidity, 74 per cent.; wind, 10 miles an hour. | 144 | 1881. May 5 | DuPont's I. K. A.; density, 1.725; granulation, 2,200. | 2 | 8 | Hotchkiss triple-wall shell, two brass bands, Hotchkiss percussion fuse. | 12 | 4¼ | — 5 | 9¼ | 4¼ | From front and left. | Fired at 500-yard target. Target 11′ by 52′, made of 1″ spruce boards. Pieces through, 398; pieces not through, 148; total, 546. Target No. 1. | 30′ short; burst on striking. |
| | 145 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 45′ short; did not burst. |
| | 146 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 50′ short; burst on striking. |
| | 147 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 60′ short; burst on striking. |
| | 148 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 70′ short; burst on striking. |
| | 149 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 40′ short; ricochetted and burst 40′ beyond target. |
| | 150 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 80′ short; burst on striking. |
| | 151 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 70′ short; burst to left of target and thrown out of target record on account of having been aimed at 1,000-yard target. |
| | 152 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 75′ short; burst on striking. |
| | 153 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | Do. |
| | 154 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | Do. |
| | 155 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | Do. |
| | 156 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | Do. |
| | 157 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 50′ short; burst on striking. |
| | 158 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 75′ short; ricochetted and burst 40′ beyond target. |
| | 159 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 75′ short; burst on striking. |
| | 160 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | Do. |
| | 161 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 60′ short; burst on striking. |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 162 | May 5 | ......do .............. | 2 | 8 | ......do .............. | 12 | $4\frac{1}{2}$ | — 5 | $9\frac{1}{2}$ | $4\frac{1}{2}$ | From front and left. | | 65′ short; burst on striking. |
| | 163 | May 5 | ......do .............. | 2 | 8 | ......do .............. | 12 | $4\frac{1}{2}$ | — 5 | $9\frac{1}{2}$ | $4\frac{1}{2}$ | | | 70′ short; burst on striking. |
| | 164 | May 5 | ......do .............. | 2 | 8 | ......do .............. | 12 | $4\frac{1}{2}$ | — 5 | $9\frac{1}{2}$ | $4\frac{1}{2}$ | | | Do. |
| Barometer, 30.35; thermometer, 54; relativehumidity, 74 per cent.; wind, 9 miles an hour. | 165 | May 5 | ......do .............. | 2 | 8 | Hotchkiss single-wall shell, one brass band (4 inches long) Hotchkiss percussion fuze. | 11 | .... | — 5 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | Fired at 500-yard target, sighting shots. | 50′ short; burst on striking. |
| | 166 | May 5 | ..... do .............. | 2 | 8 | ......do .............. | 11 | .... | — 5 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | Direct hit; burst beyond target. |
| | 167 | May 5 | ..... do .............. | 2 | 8 | ..... do .............. | 11 | .... | —10 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 10′ short; burst on striking. |
| | 168 | May 5 | ......do .............. | 2 | 8 | ......do .............. | 11 | .... | —15 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | Fired at 500-yard target. Target 11′ by 52′, made of 1″ spruce boards. Target No. 2. Pieces through, 49. | 70′ short; burst on striking. |
| | 169 | May 5 | ......do .............. | 2 | 2 | ......do .............. | 11 | .... | —15 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 70′ short; burst beyond target. |
| | 170 | May 5 | ......do .............. | 2 | 8 | ......do .............. | 11 | .... | —15 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 70′ short; burst on striking. |
| | 171 | May 5 | ......do .............. | 2 | 8 | ......do .............. | 11 | .... | —15 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | Do. |
| | 172 | May 5 | ......do .............. | 2 | 8 | ......do .............. | 11 | .... | —15 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 20′ short; burst on striking. |
| | 173 | May 5 | ......do .............. | 2 | 8 | ......do .............. | 11 | .... | —15 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 225′ short; burst on striking. |
| Barometer, 30.14, thermometer, 58; relativehumidity, 73 per cent.; wind, 16 miles an hour. | 174 | May 7 | ......do .............. | 2 | 8 | Hotchkiss single-wall shell altered by copper band put on in rear of corrugated band, at Sandy Hook; Hotchkiss percussion fuzes. | 11 | 12 | — 5 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | Fired at 500-yard target. Target 11′ by 52′, made of 1″ spruce boards. Pieces through, 172; pieces not through, 19; total, 191. Target No. 3. | 65′ short; burst on striking. |
| | 175 | May 7 | ......do .............. | 2 | 8 | ......do .............. | 11 | 12 | — 5 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | Do. |
| | 176 | May 7 | ......do .............. | 2 | 8 | ......do .............. | 11 | 12 | — 5 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 50′ short; burst on striking. |
| | 177 | May 7 | ......do .............. | 2 | 8 | ......do .............. | 11 | 12 | — 4 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 65′ short; burst on striking. |
| | 178 | May 7 | ......do .............. | 2 | 8 | ......do .............. | 11 | 12 | — 4 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 65′ short; burst beyond target. |
| | 179 | May 7 | ......do .............. | 2 | 8 | ......do .............. | 11 | 12 | — 4 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 100′ short; burst on striking. |
| | 180 | May 7 | ......do .............. | 2 | 8 | ......do .............. | 11 | 12 | — 4 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 55′ short; burst on striking. |
| | 181 | May 7 | ......do .............. | 2 | 8 | ......do .............. | 11 | 12 | — 4 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | Do. |
| | 182 | May 7 | ......do .............. | 2 | 8 | ......do .............. | 11 | 12 | — 4 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 125 short; burst on striking. |
| | 183 | May 7 | ......do .............. | 2 | 8 | ..... do .............. | 11 | 12 | — 4 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 65′ short; did not burst. |
| | 184 | May 7 | ......do .............. | 2 | 8 | ......do .............. | 11 | 12 | — 4 | $10\frac{3}{4}$ | $11\frac{1}{2}$ | | | 50 short; burst on striking. |

*Target record of firing with* 3.15 *inches* (8cm.) *Hotchkiss breech-loading rifle No.* 787, *at Sandy Hook, N. J.*—Continued.

| | No. of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs. | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs. | Projectile. Weight. Oz. | Elevation in degrees. | Length of projectile. | Bursting charge. | Direction of wind as regards line of fire. | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1881. | | | | | | | ° ′ | *In.* | *Oz.* | | | |
| Barometer, 30.31; thermometer, 54; relative humidity, 74 per cent.; wind, 10 miles an hour. | 144 | May 5 | DuPont's I. K. A.; density, 1.725; granulation, 2,200. | 2 | 8 | Hotchkiss triple-wall shell, two brass bands, Hotchkiss percussion fuze. | 12 | 4¼ | — 5 | 9¼ | 4¼ | From front and left. | Fired at 500-yard target. Target 11′ by 52′, made of 1″ spruce boards. Pieces through, 398; pieces not through, 148; total, 546. Target No. 1. | 30′ short; burst on striking. |
| | 145 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 45′ short; did not burst. |
| | 146 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 50′ short; burst on striking. |
| | 147 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 60′ short; burst on striking. |
| | 148 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 70′ short; burst on striking. |
| | 149 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 40′ short; ricochetted and burst 40′ beyond target. |
| | 150 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 80′ short; burst on striking. |
| | 151 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 70′ short; burst to left of target and thrown out of target record on account of having been aimed at 1,000-yard target. |
| | 152 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 75′ short; burst on striking. |
| | 153 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | Do. |
| | 154 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | Do. |
| | 155 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | Do. |
| | 156 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | Do. |
| | 157 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 50′ short; burst on striking. |
| | 158 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 75′ short; ricochetted and burst 40′ beyond target. |
| | 159 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 75′ short; burst on striking. |
| | 160 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | Do. |
| | 161 | May 5 | ......do | 2 | 8 | ......do | 12 | 4¼ | — 5 | 9¼ | 4¼ | | | 60′ short; burst on striking. |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 162 | May 5 | ......do | 2 | 8 | ......do | 12 | 4½ | — 5 | 9½ | 4½ | From front and left. | | 65′ short; burst on striking. |
| | 163 | May 5 | ......do | 2 | 8 | ......do | 12 | 4½ | — 5 | 9½ | 4½ | | | 70′ short; burst on striking. |
| | 164 | May 5 | ......do | 2 | 8 | ......do | 12 | 4½ | — 5 | 9½ | 4½ | | | Do. |
| Barometer, 30.35; thermometer, 54; relative humidity, 74 per cent.; wind, 9 miles an hour. | 165 | May 5 | ......do | 2 | 8 | Hotchkiss single-wall shell, one brass band (4 inches long) Hotchkiss percussion fuze. | 11 | .... | — 5 | 10¾ | 11½ | | Fired at 500-yard target, sighting shots. | 50′ short; burst on striking. |
| | 166 | May 5 | ......do | 2 | 8 | ......do | 11 | .... | — 5 | 10¾ | 11½ | | | Direct hit; burst beyond target. |
| | 167 | May 5 | ......do | 2 | 8 | ......do | 11 | .... | —10 | 10¾ | 11½ | | | 10′ short; burst on striking. |
| | 168 | May 5 | ......do | 2 | 8 | ......do | 11 | .... | —15 | 10¾ | 11½ | | Fired at 500-yard target. Target 11′ by 52′, made of 1″ spruce boards. Target No. 2. Pieces through, 49. | 70′ short; burst on striking. |
| | 169 | May 5 | ......do | 2 | 2 | ......do | 11 | .... | —15 | 10¾ | 11½ | | | 70′ short; burst beyond target. |
| | 170 | May 5 | ......do | 2 | 8 | ......do | 11 | .... | —15 | 10¾ | 11½ | | | 70′ short; burst on striking. |
| | 171 | May 5 | ......do | 2 | 8 | ......do | 11 | .... | —15 | 10¾ | 11½ | | | Do. |
| | 172 | May 5 | ......do | 2 | 8 | ......do | 11 | ... | —15 | 10¾ | 11½ | | | 20′ short; burst on striking. |
| | 173 | May 5 | ......do | 2 | 8 | ......do | 11 | ... | —15 | 10¾ | 11½ | | | 225′ short; burst on striking. |
| Barometer, 30.14, thermometer, 58; relative humidity, 73 per cent.; wind, 16 miles an hour. | 174 | May 7 | ......do | 2 | 8 | Hotchkiss single-wall shell altered by copper band put on in rear of corrugated band, at Sandy Hook; Hotchkiss percussion fuzes. | 11 | 12 | — 5 | 10¾ | 11½ | | Fired at 500-yard target. Target 11′ by 52′, made of 1″ spruce boards. Pieces through, 172; pieces not through, 19; total, 191. Target No. 3. | 65′ short; burst on striking. |
| | 175 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 5 | 10¾ | 11½ | | | Do. |
| | 176 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 5 | 10¾ | 11½ | | | 50′ short; burst on striking. |
| | 177 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11½ | | | 65′ short; burst on striking. |
| | 178 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11½ | | | 65′ short; burst beyond target. |
| | 179 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11½ | | | 100′ short; burst on striking. |
| | 180 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11½ | | | 55′ short; burst on striking. |
| | 181 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11½ | | | Do. |
| | 182 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11½ | | | 125 short; burst on striking. |
| | 183 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11½ | | | 65′ short; did not burst. |
| | 184 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11½ | | | 50 short; burst on striking. |

*Target record of firing with* 3.15 *inches* (8$^{cm}$.) *Hotchkiss breech-loading rifle No.* 787, *at Sandy Hook, N. J.*—Continued.

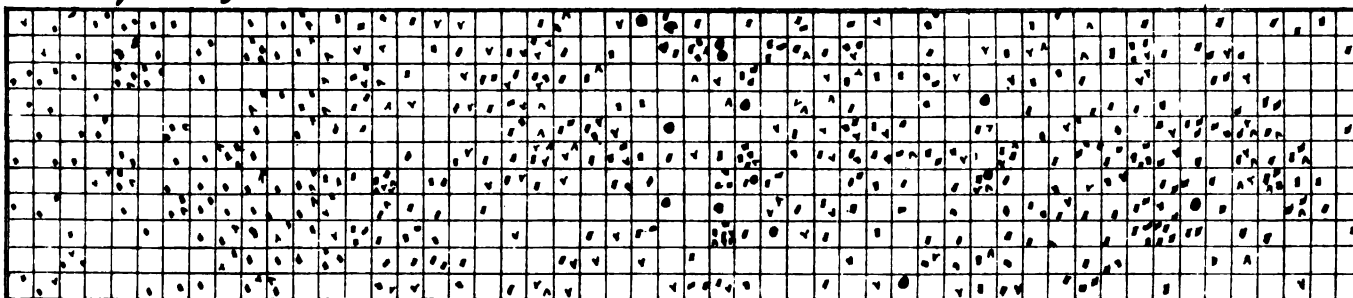
| | No. of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs. | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs. | Projectile. Weight. Oz. | Elevation in degrees. | Length of projectile. | Bursting charge. | Direction of wind as regards line of fire. | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | ° ′ | *In.* | *Oz.* | | | |
| Barometer, 30.14; thermometer, 58; relative humidity, 73 per cent.; wind, 16 miles an hour. | 185 | May 5 | Du Pont's I. K. A.; density, 1.725; granulation, 2,200. | 2 | 8 | Hotchkiss single-wall shell altered by copper band put on in rear of corrugated band, at Sandy Hook, Hotchkiss percussion fuzes. | 11 | 12 | — 4 | 10¾ | 11¼ | From front and left. | Fired at 500-yard target. Target 11 by 52', made of 1" spruce boards. Pieces through, 172; pieces not through, 19; 191. Target No. 3. | 50' short; burst on striking. |
| | 185 | 1881. May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11¼ | | | 65' short; burst on striking. |
| | 186 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11¼ | | | Do. |
| | 187 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11¼ | | | Do. |
| | 188 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11¼ | | | Do. |
| | 189 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11¼ | | | 50' short; burst on striking. |
| | 190 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11¼ | | | 330' short; burst on striking. |
| | 191 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11¼ | | | 65' short; burst 300 yards beyond target. |
| | 192 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11¼ | | | 50' short; burst on striking. |
| | 193 | May 7 | ......do | 2 | 8 | ......do | 11 | 12 | — 4 | 10¾ | 11¼ | | | 60' short; burst on striking. |

Tin cases containing powder charge did not extract freely in any of the rounds from 126 to 193, inclusive; at round 136 had to be forced out of chamber by rammer from muzzle.

PLATE I.

Target Record of 8 c/m (3.15) Hotchkiss B. L. Rifle (triple wall shell)
at Sandy Hook N. J. May 5th 1881
Target 500 Yards from gun

Number of shell fired 30 Total number of hits in target 546



Target 11'x52' Made of 1" Spruce board. Pieces through 398. Pieces not through 148 - Pieces through marked ● not through ▼

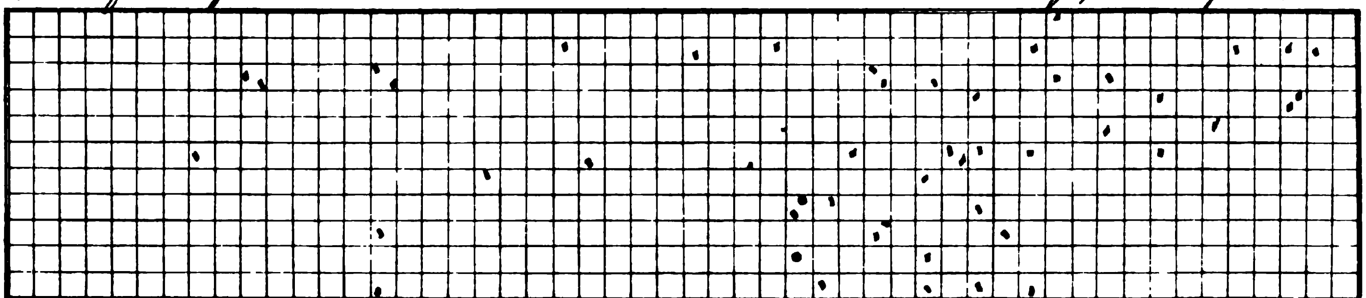
1_Did not burst
2.-burst beyond target

Wind 12 miles an hour.

Target Record of 8 c/m (3.15") Hotchkiss B.L. Rifle (Single wall shell)
at Sandy Hook N.J. May 5th 1881
Target 500 Yards from gun.

Number of shell fired 6

Number of pieces in target 49



Target 11' X 52' Made of 1" Spruce boards

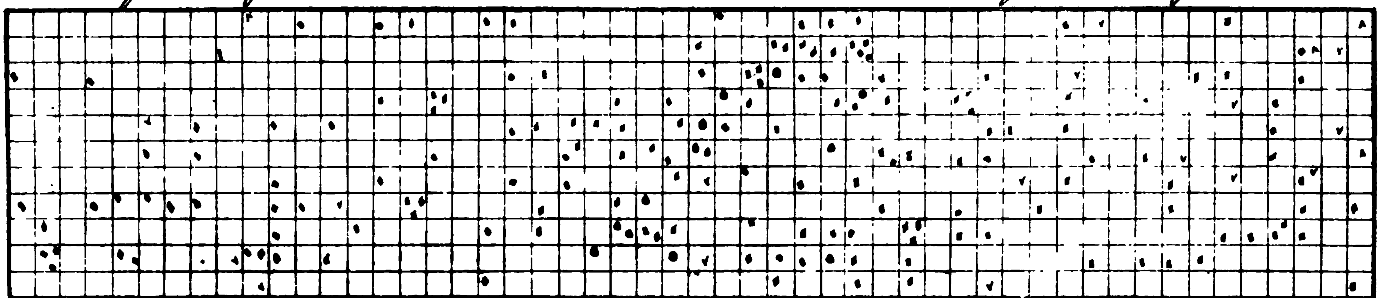
Pieces through 49 –

1 burst beyond target.

Wind 12 miles an hour

Target Record of 8c/m (3.15") Hotchkiss B.L. Rifle (Single wall shell)
at Sandy Hook N. J. May 7th 1881
Target 500 Yards from gun

Number of shell fired 20 Total number of hits in target 191



Target 11' x 52' Made of 1 inch spruce boards. Pieces through 172 Pieces not through 19- Pieces through marked by hit through a

1_did not burst
2_burst beyond target

Wind 6 miles an hour

## APPENDIX 38f.

### REPORT ON THE HOTCHKISS BREECH-LOADING MOUNTAIN GUNS, CALIBER 1".65.

[One plate.]

JULY 29, 1881.

The CHIEF OF ORDNANCE, U. S. A.,
*Washington, D. C.:*

SIR: I have the honor to state that the Ordnance Board, after a careful consideration of the subject of the adoption of a light portable field-piece, for the special use of our frontier service (replacing the obsolete mountain howitzer), and an examination of the various reports which have, from time to time, been referred to it, submits the following recommendations:

#### I.—THE GUN.

In considering the caliber, and consequent range and effectiveness, for a gun of this nature, the question at once arranges itself under the main points of weight and portability; the weight being limited to the carrying capacity of a single pack-animal, unless a jointed system be adopted; and this, from the rough character of our frontier service, is thought to be decidedly objectionable. Portability being dependent of course on lightness, the least weight of piece consistent with the accomplishment of the work required, should obtain. The reports from the field in regard to the Hotchkiss mountain rifle, caliber 1."65, weighing but 120 pounds, speak most highly of it for range and accuracy; and it is thought to possess all the requirements of a gun for our mountain service and that of the plains. The board, therefore, in view of the favorable reports from the field as to its utility and portability, and its general adaptability to the practical wants of the service of the frontier, recommends its definite adoption for service.

#### II.—THE CARRIAGE (HOTCHKISS MOUNTAIN GUN.)

The present carriage arranged for shaft-draft, without limber, has been shown by practical trial in the field to be entirely unsuitable as a method of transportation.

When the gun is to be transported on its carriage, the desirability of a limber is clearly shown, both as a means of carrying a larger supply of ammunition and of ease of traction, and especially so, as it is evident that whenever it may be desired to transport the gun on its carriage, the limber can always accompany it. It is therefore recommended that the present method of shaft-draft be abandoned, and that a suitably arranged limber, with pole and harness for the horses, be furnished with this gun.

#### III.—PACKING.

In regard to the transportation of the mountain gun, with its carriage, implements, and ammunition, by means of pack-animals, the board has examined the various methods brought before it. The manner of packing recommended by the board of officers convened at Saint Paul by the commanding general, Department of Dakota (see Ordnance

Note 149), and Moore's improved method, as used in the Department of the Missouri, seem alike in many features, and seem about equally well adapted for the end in view; but as this is a question only to be determined by practical trial, it is recommended that a limited number of outfits on each system be manufactured and issued for comparative trial in the field. With either, it is evident that practical instruction will be necessary.

For the carriage of cartridges with pack-animals, the Madigan box seems well adapted, and has the decided advantage of accessibility to the cartridges without unlashing. It is recommended that this manner of carrying ammunition by packing, be, on every opportunity, tried as thoroughly as possible, and full reports rendered, as the result of the trial may have a direct bearing on the supply of small-arm ammunition on the field of battle, a subject which, in the plain approach of magazine arms, is one of grave importance.

## IV.—AMMUNITION (HOTCHKISS MOUNTAIN GUN).

The main objection to the ammunition issued with this gun, seems to be an occasional failure of the percussion fuze, too insecure an attachment of the cartridge-case to the projectile, and missfires. The same fuze of later manufacture, has given excellent results at Sandy Hook, and the attachment of the cartridge-case to the projectile can readily be made stronger. The missfires it is thought, in many instances, arise from the valve at the base of the cartridge-case leading to the charge, being either rusted in place or too rigidly fixed in fabrication.

Observing that the valve is properly loosened prior to filling the case, will doubtless remedy this defect; and using a longer primer, made for the purpose, will obviate the missfires due to the primers issued with the earlier ammunition.

In this connection the board would suggest the advisability of the department now undertaking the manufacture of both the cartridges and fuzes for this gun. They are at present purchased abroad.

Attaching a firing-pin to a gun of this nature, as has been suggested in reports from the field, would necessarily introduce a new complication in the breech fermeture, and would not, it is thought, have any advantage over a primer of proper dimensions.

A description of this gun is given in the Report of Chief of Ordnance for 1880, pages 132 and 133. A table of ranges was determined by the board for this gun up to and including 15° elevation, and will be found in the inclosed records of firing of guns Nos. 47 and 49. Gun No. 49 was fired at a target a mile distant, and its record is also herewith appended.

*Target record of firing with Hotchkiss mountain gun, No. 49, caliber 1.65 inches, at Sandy Hook, N. J.*

| | Number of fire. | Time. | Powder. | | | Projectile. | | | Elevation, in degrees. | Direction of wind as regards line of fire. | Range, in yards. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Weight. | | Kind. | Weight. | | | | | |
| | | | | Lbs | Oz. | | Lbs | Oz. | | | | |
| 9 a. m.: Barometer, 30.085; thermometer, 54; rel. humidity, 93 per cent.; wind, east, 22 mls. | 1 | 1880. May 19 | Old mortar powder. | .... | 5¼ | Hotchkiss shell, with percussion fuze in point. | 1 | 15 | 0 | From left to right. | ........ | Fired down beach. Burst on striking. Cartridge-case loaded and extracted easily. |
| | 2 | May 19 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 0 | | ........ | Fired over water. Burst on striking. Cartridge-case loaded and extracted easily. |
| 3 p. m.: Barometer, 30.064; thermometer, 55; rel. humidity, 87 per cent.; wind, east, 17 mls. | 3 | May 19 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 0 | | ........ | Fired down beach. Burst on striking. Cartridge-case loadod and extracted easily. |
| | 4 | May 19 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 0 | | ........ | Do. |
| | 5 | May 19 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 0 | | ........ | Fired over water. Burst on striking. Cartridge-case loaded and extracted easily. |
| | 6 | May 19 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 0 | | ........ | Do. |
| Barometer, 29.624; thermometer, 85; rel. humidity, 72 per cent.; wind, 13 miles an hour. | 7 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 4 | From front and left. | Lost .. | 1,806 yards average range. |
| | 8 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 4 | | 1, 875 | |
| | 9 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 4 | | 1, 762 | |
| | 10 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 4 | | 1, 781 | |
| | 11 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 5 | | 2, 105 | 2,086 yards average range. |
| | 12 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 5 | | 2, 046 | |
| | 13 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 5 | | 2, 107 | |
| | 14 | July 16 | ....do ...... | .... | 54 | ....do .......... | 1 | 15 | 6 | | 2, 302 | 2,312 yards average range. |
| | 15 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 6 | | 2, 235 | |
| | 16 | July 16 | ... do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 6 | | 2, 398 | |
| | 17 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 7 | | 2, 553 | 2,597 yards average range. |
| | 18 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 7 | | 2, 606 | |
| | 19 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 7 | | 2, 633 | |

*Target record of firing with Hotchkiss mountain gun, No. 49, caliber 1.65 inches, at Sandy Hook, N. J.*—Continued.

| | Number of fire. | Time. | Powder. | | | Projectile. | | | Elevation, in degrees. | Direction of wind as regards line of fire. | Range, in yards. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Weight. Lbs. | Weight. Oz. | Kind. | Weight. Lbs. | Weight. Oz. | | | | |
| Barometer, 29.624; thermometer, 85; rel. humidity, 72 per cent.; wind, 13 miles an hour. | 20 | 1880. July 16 | Old mortar powder. | .... | 5½ | Hotchkiss shell, with percussion fuze in point. | 1 | 15 | 8 | From front and left. | 2,800 | 2,847 yards average range. |
| | 21 | July 16 | ....do ...... | .... | 5½ | ... do .......... | 1 | 15 | 8 | | 2,862 | |
| | 22 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 8 | | 2,879 | |
| | 23 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 9 | | 3,041 | 3,046 yards average range. |
| | 24 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 9 | | Lost .. | |
| | 25 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 9 | | 3,058 | |
| | 26 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 9 | | 3,038 | |
| | 27 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 10 | | 3,318 | 3,338 yards average range. |
| | 28 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 10 | | 3,344 | |
| | 29 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 10 | | 3,352 | |
| | 30 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 11 | | 3,485 | 3,517 yards average range. |
| | 31 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 11 | | 3,515 | |
| | 32 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 11 | | 3,552 | |
| | 33 | July 16 | ....do ...... | ... | 5½ | ....do .......... | 1 | 15 | 12 | | 3,654 | 3,637 yards average range. |
| | 34 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 12 | | Lost .. | |
| | 35 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 12 | | ..do ... | |
| | 36 | July 16 | ....do ...... | .... | 5½ | ....do .......... | 1 | 15 | 12 | | ..do ... | |
| | 37 | July 16 | ....do ...... | .. | 5½ | ....do ...... | 1 | 15 | 12 | | ..do .. | |
| | 38 | July 16 | ....do ...... | | 5½ | ....do ...... | 1 | 15 | 12 | | 3,620 | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Barometer, 29.624; thermometer, 85; rel. humidity, 72 per cent.; wind, 13 miles an hour. | 39 | July 16 | ....do ...... | .... | 5¼ | ....do ........ | 1 | 15 | 15 | From front and left. | Lost .. |
| | 40 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 15 | | ..do ... |
| | 41 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 15 | | ..do ... 4,203 yards average range. |
| | 42 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 15 | | 4,224 |
| | 43 | July 16 | ... do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 15 | | 4,182 |
| | 44 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 4° 15′ | | ....... Fired at mile target. Sighting shots. |
| | 45 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 4 30 | | ....... |
| | 46 | July 16 | ... do ...... | | 5¼ | ....do .......... | 1 | 15 | 4 20 | | .... ... |
| | 47 | July 16 | ....do ...... | ... | 5¼ | ....do .......... | 1 | 15 | 4 15 | | ....... |
| | 48 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 4 10 | | ....... |
| | 49 | July 16 | ....do ...... | ... | 5¼ | ....do .......... | 1 | 15 | 4 10 | | ....... |
| | 50 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 4 10 | | Fired at mile target. Target 20′×40′, made of 1″ spruce boards. |
| | 51 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 4 10 | | |
| | 52 | July 16 | ....do ...... | .. | 5¼ | ....do .......... | 1 | 15 | 4 10 | | |
| | 53 | July 16 | ....do ...... | .... | 5¼ | ....do ...... .... | 1 | 15 | 4 10 | | |
| | 54 | July 16 | ....do ...... | .. | 5¼ | ....do .......... | 1 | 15 | 4 10 | | |
| | 55 | July 16 | ....do ...... | .... | 5¼ | ....do .......... | 1 | 15 | 4 10 | | |

| No. | Distance from center of target, in feet. | | | | Distance from center of impact, in feet. | | | |
|---|---|---|---|---|---|---|---|---|
| | Vertical. | | Horizontal. | | Vertical. | | Horizontal. | |
| | Above. | Below. | Right. | Left. | Above. | Below. | Right. | Left. |
| 50 | 6.00 | ....... | ....... | 9.00 | 1.93 | ....... | ....... | 4.57 |
| 51 | 7.67 | ....... | .17 | ....... | 3.60 | .. .... | 4.60 | ....... |
| 52 | 8.00 | ....... | ....... | 5.83 | 3.93 | ....... | ....... | 1.40 |
| 53 | ....... | 1.33 | ....... | 1.50 | ....... | 5.40 | 2.93 | ....... |
| 54 | 6 feet in front of target. | | | .. .... | ....... | ....... | .... . | ....... |
| 55 | ....... | ....... | ....... | 6.00 | .... .. | 4.07 | ....... | 1.57 |
| | 21.67 | 1.33 | .17 | 22.33 | 9.46 | 9.47 | 7.53 | 7.54 |
| | 20.34 ÷ 5 = 4.07 | | 22.16 ÷ 5 = 4.43 | | 18.93 ÷ 5 = 3.79 | | 15.07 ÷ 5 = 3.01 | |

Mean vertical deviation from center of impact.........3′.79
Mean horizontal deviation from center of impact.......3′.01
Mean deviation from center of impact..................4′.84

*Target record of firing with Hotchkiss mountain gun No. 49, caliber 1.65 inches, at Sandy Hook, N. J.*—Continued.

| | Number of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs | Projectile. Weight. Oz. | Elevation in degrees. | Direction of wind as regards line of fire. | Range, in yards. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Barometer, 29.61; thermometer, 85; rel. humidity, 53 per cent.; wind, 25 miles an hour. | 56 | 1881. July 21 | Old mortar powder. | | 5¼ | Hotchkiss shell, with ordinary point fuze. | 1 | 15 | 1¾ | From rear and right. | Bursting charge; 1½ ozs. musket powder. | Fired down beach. Struck about 1,000 yards from gun and burst. Gun loaded and extracted easily. |
| | 57 | July 21 | ...do | | 5¼ | ...do | 1 | 15 | 1¾ | | | |
| | 58 | July 21 | ...do | | 5¼ | ...do | 1 | 15 | 1¾ | | | |
| | 59 | July 21 | ...do | | 5¼ | ...do | 1 | 15 | 1¾ | | | |
| | 60 | July 21 | ...do | | 5¼ | ...do | 1 | 15 | 1¾ | | | |

*Target record of firing with Hotchkiss mountain gun No. 47, caliber 1.65 inches, at Sandy Hook, N. J.*

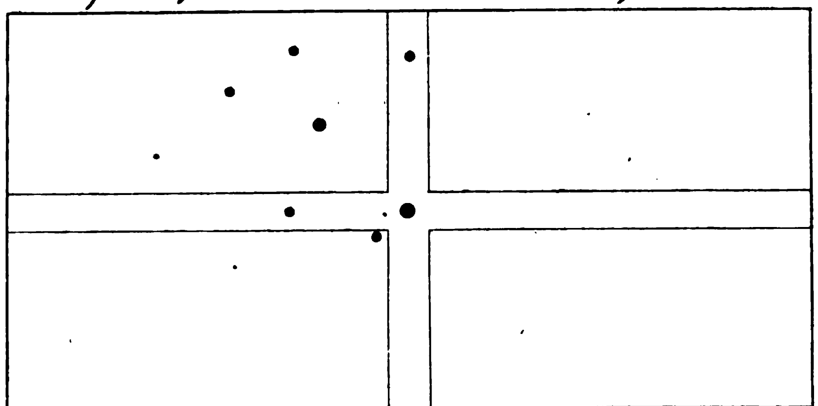
| | Number of fire. | Time. | Powder. Kind. | Powder. Weight. Lbs | Powder. Weight. Oz. | Projectile. Kind. | Projectile. Weight. Lbs | Projectile. Weight. Oz. | Elevation in degrees. | Direction of wind as regards line of fire. | | Ranges, yards. | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Barometer, 29.556; thermometer, 55; relative humidity, 93 per cent.; wind, SW., 18 miles. | 1 | 1880. Feb. 13 | Old mortar | | 5½ | Hotchkiss shell, with percussion fuze in point. | 1 | 15 | 0 | From right to left. | Fired down beach for ranges. | 357 | 367 yards. Average range. | Cartridge case loaded and extracted easily. |
| | 2 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 0 | | | 369 | | Do. |
| | 3 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 0 | | | 374 | | Do. |
| | 4 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 1 | | | 728 | 733 yards. Average range. | Do. |
| | 5 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 1 | | | 734 | | Do. |
| | 6 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 1 | | | 736 | | Cartridge case loaded and extracted easily. Shell did not burst on striking. |
| | 7 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 2 | | | 989 | 1,000 yards. Average range. | Cartridge case loaded and extracted easily. |
| | 8 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 2 | | | 1,004 | | Do. |
| | 9 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 2 | | | 1,017 | | Do. |
| | 10 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 3 | | | 1,378 | 1,388 yards. Average range. | Do. |
| | 11 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 3 | | | 1,380 | | Do. |
| | 12 | Feb. 13 | .. do | | 5½ | do | 1 | 15 | 3 | | | 1,407 | | Do. |

PLATE I.

Target Record of 1.65" Hotchkiss Mountain Gun #49
at Sandy Hook N.J. July 16 - 1880
Target One mile from gun

Number of shot fired 6

Number of direct hits 5



● Point aimed at.
● Center of impact

Target 20'x40' made of 1" Spruce board

Mean vertical deviation from center of impact 3.79'
Mean horizontal deviation from center of impact 3.0'
Mean deviation from center of impact. 4.84'

Wind 13 miles an hour

# INDEX.

REPORTS OF THE CONSTRUCTOR OF ORDNANCE.



REPORTS OF THE ORDNANCE BOARD.